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The Alfalfa Plant Bug

Adelphocoris lineolatus (Goeze) and Other Miridae (Hemiptera) in Relation to Alfalfa-Seed Production in Minnesota

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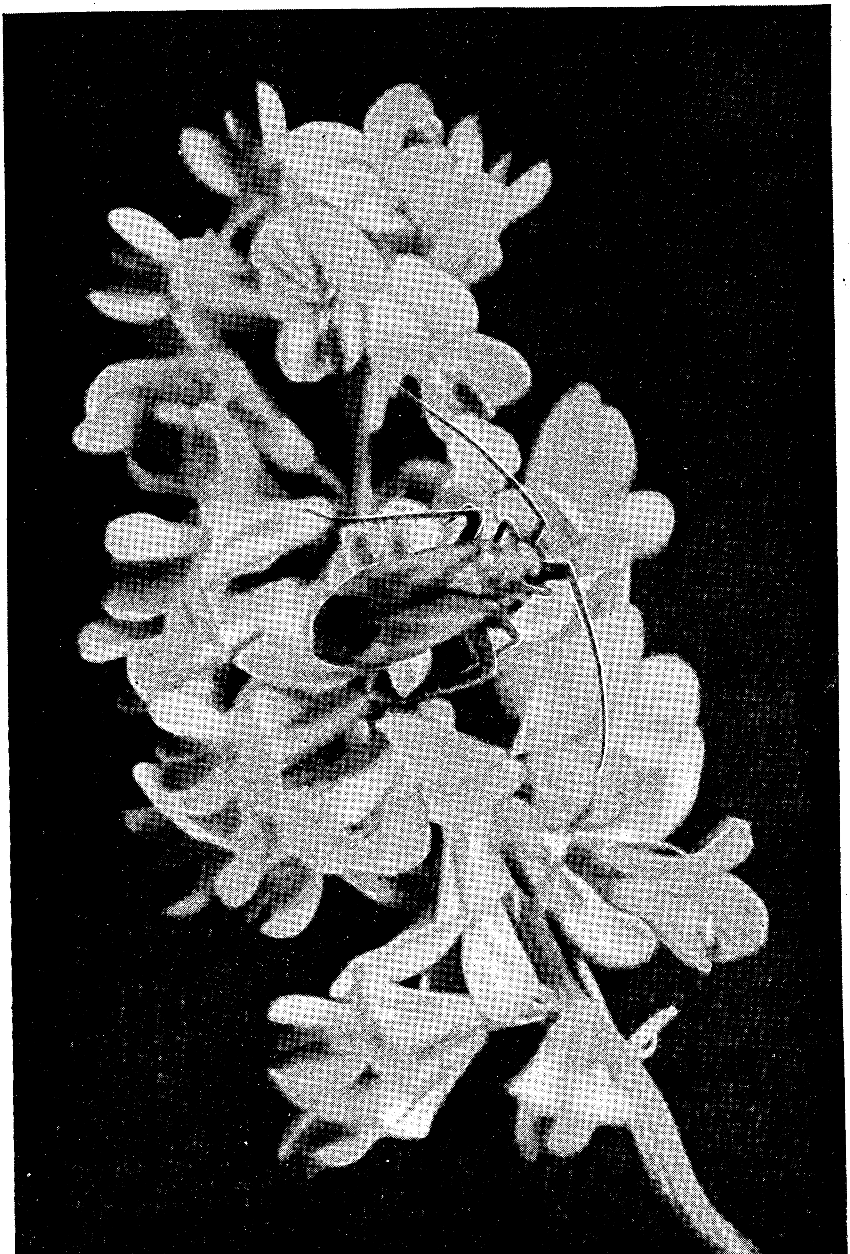

FIG. 1. The alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), on alfalfa (X 4)

The Alfalfa Plant Bug

Adelphocoris lineolatus (Goeze) and Other Miridae (Hemiptera) in Relation to Alfalfa-Seed Production in Minnesota[1]

John H. Hughes

Introduction

IN JUNE, 1939, several insect specimens, collected on alfalfa (*Medicago sativa* L.) and sweet clover (*Melilotus* sp.) in Todd County, Minnesota, were received by the Division of Entomology and Economic Zoology, University of Minnesota, for identification. These insects were identified as the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), Family Miridae, Order Hemiptera.

For several years prior to 1939 the Division of Entomology and Economic Zoology and the Minnesota State Entomologist's Office had received complaints from Minnesota alfalfa-seed growers regarding the reduced alfalfa-seed yields on their farms. A survey made in August, 1939, showed *A. lineolatus* to be abundant in alfalfa fields throughout the state.

Adults and nymphs of this species have long been recognized as serious crop pests in Europe. Vassiliev *(25)* stated that this insect, known as the lucerne leaf bug in Europe, was the most important pest on alfalfa in Russia for that year. Moroshkina and Akimova *(11)* and others have since shown this species to be an important factor in alfalfa-seed loss in Europe.

Since this insect was known to be a serious alfalfa pest in Europe, studies were initiated in the fall of 1939 and the spring of 1940 on the life history and biology of *A. lineolatus* on alfalfa.

[1] A cooperative project of the State Entomologist of the Minnesota Department of Agriculture, the Iron Range Resources and Rehabilitation Commission, and the Minnesota Agricultural Experiment Station. The State Entomologist made the initial surveys and contributed a part of the supervision during five seasons. The Iron Range Resources and Rehabilitation Commission financed the research in the field for two seasons. The Minnesota Agricultural Experiment Station contributed a part of the supervision for five seasons, financed the research in the field for one season, and furnished laboratory space, supplies, and equipment for carrying on the work.

Preliminary studies soon indicated that this insect primarily, and at least two others secondarily, was potentially responsible for the reduction in the alfalfa-seed crop. The problem then resolved itself into a study of the life history of *A. lineolatus* in Minnesota, the exact nature of the injury to the alfalfa plant which resulted in the reduced seed crop, and the possible methods of control of the insect in alfalfa fields.

This bulletin is a report of the results of the investigations concerning *A. lineolatus* and other plants bugs and their relation to the culture of alfalfa for seed production.

History and Distribution

ADELPHOCORIS LINEOLATUS (GOEZE)

The alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), was first described by Goeze *(5)* as *Cimex lineolatus.* The synonymy for this species is extensive and is detailed by Reuter *(14),* Knight *(7),* and others. It had been placed in at least seven genera by the close of the 19th century when Reuter *(14)* called it *A. lineolatus* (Goeze). He gave four varieties for the species; namely, *implagiata* Westh., *typica, binotata* Hahn, and *bisbipunctata* Reut. Knight *(7)* compared specimens from Nova Scotia with some *A. lineolatus* (Goeze) determined by Reuter and stated "that the specimens are structurally identical but pertain to variety *binotata* Hahn." This species, which has been known in Europe as the "lucerne leaf bug," was called the "alfalfa plant bug" by Knight *(9).*

The earliest record of *A. lineolatus* was from the old world; it now occurs in Europe, Asia, Africa, and North America. This species was reported from Finland, Russia, Syria, India, Persia, Siberia, Mongolia, China, Japan, Tunisia, and Algeria by Oshanin *(12).* Butler *(2)* stated that it was also present in the British Isles. It was in Germany and Sweden more than 100 years ago according to Hahn *(6)* who called it *Phytocoris binotatus* which Reuter *(14)* gave as a variety.

In North America the first specimens were collected at Cape Breton Island, Nova Scotia, August, 1917. Knight *(7)* identified these insects as *A. lineolatus* (Goeze).

Mr. R. P. Gorham, Canadian Department of Agriculture, recently reported that this species is common in parts of New Brunswick. Dr. C. E. Mickel observed it in abundance on alfalfa in Manitoba, 1941.

The species was first reported in the United States by Knight *(8)* who collected it at Ames, Iowa, June 18, 1929. He later stated that it may have been imported as eggs in alfalfa seeds. It is the writer's opinion that eggs may also have been in tiny pieces of alfalfa stem in the imported seed. During this study as many as 19 *A. lineolatus* eggs have been observed crowded in a piece of alfalfa stem only 5 mm. in length. There has been a gradual spread of this species to neighboring states and to Canada. It was in Minnesota as early as 1933 and has since been reported in Illinois, Missouri, North Dakota, South Dakota, Wisconsin, Nebraska, Michigan, and Kansas.

A. lineolatus was first collected in Ramsey County, Minnesota, in 1933 and at St. Paul in 1934. From that time to 1939, when a study of the species was begun, it became generally distributed throughout Minnesota on alfalfa and sweet clover. These insects have also been collected from additional plants including potatoes, *Solanum tuberosum* L.; red clover, *Trifolium pratense* L.; alsike, *T. hybridum* L.; buckwheat, *Fagopyrum esculentum* Moench.; and golden rod, *Solidago* spp.

An examination of the Minnesota Miridae Collection of the Division of Entomology and Economic Zoology, University of Minnesota, revealed a total of 148 specimens of *A. lineolatus* (1933-1938). Four specimens were recorded from Ramsey and Washington counties in 1933; two from Houston and Ramsey counties (St. Paul 1) in 1934; 95 from Big Stone, Cass, Goodhue, Kandiyohi, Lac qui Parle, Lake, Le Sueur, Lincoln, Lyon, Mille Lacs, Morrison, Olmsted, Pipestone, Ramsey, Rock, Scott, Traverse, Wadena, Washington, and Wright counties in 1935; 19 from Brown, Clearwater, Freeborn, Norman, Pennington, Polk, Ramsey, Renville, Steele, Todd, and Yellow Medicine counties in 1936; three from Norman, Rice, and St. Louis counties in 1937; 25 from Clearwater, Kandiyohi, Pine, Ramsey, Rock, and Yellow Medicine counties in 1938.

During the years 1939 to 1942, inclusive, *A. lineolatus* has been found in all alfalfa and sweet clover fields examined in Minnesota.

ADELPHOCORIS RAPIDUS (SAY)

The rapid plant bug, *Adelphocoris rapidus* (Say), was first described as *Capsus rapidus* by Say *(16)*. It occurs in the United States and Canada, east of the 110th meridian, where it feeds on many plants including alfalfa and sweet clover.

LYGUS OBLINEATUS (SAY)

The tarnished plant bug, *Lygus oblineatus* (Say), was first described by Say *(16)* as *Capsus oblineatus.* Knight *(10)* states that this species has been confused with the European species, *L. pratensis* (Linnaeus), from which it differs in structure of the right genital clasper and in coloration. He called it *L. oblineatus* (Say), which name is accepted in this paper. It has also been known in recent years as *L. pratensis oblineatus* (Say).

It is commonly found in eastern United States but is also present in several western states where Stitt *(21)* found it on alfalfa. Crosby and Leonard *(4)* made a detailed study of the tarnished plant bug and prepared an extensive synonymical list for the species which they called *L. pratensis* L.

Decline of Alfalfa-Seed Yields in Minnesota

Minnesota is one of the principal alfalfa hay- and seed-producing states in the United States (see table 1).[2]

The average number of acres of alfalfa harvested for seed in Minnesota from 1930 to 1939 was 68,530 and Minnesota ranked second among the alfalfa seed-producing states. The acreage harvested for seed from 1936 to 1942 increased 190 per cent over the acreage from 1930 to 1935. More alfalfa (168,000 acres) was harvested for seed in 1940 than in any other year of the 11-year period from 1930 to 1940, inclusive. The acreage was greatly reduced in 1941 and 1942 when there were only 72,000 and 48,000 acres, respectively. Minnesota was fourth in average production from 1930 to 1939, but dropped to seventh place in 1941 and 1942. Seed yields were checked for the years 1919 to 1929, inclusive, but are not included in the table. The maximum average per acre was 1.7 bushels in 1919 and the minimum average was 1.2 bushels in 1927. The mean average for the period (1919-1929) was 1.42 bushels. The mean average for the period 1930 to 1942, inclusive, was 1.26 bushels. The mean average for the United States for this period (1930-1942) was 1.74 bushels. The yearly average for Minnesota was less than the mean average for the United States throughout this 13-year period (table 1). From 1937 to 1942 there was a definite decline in alfalfa-seed yields as can be noted in the table.

The yields per acre in some of the northern counties of the

[2] Alfalfa hay and seed figures based on reports of the Bureau of Agricultural Economics, U. S. Department of Agriculture.

Table 1. Acreage, Yield, and Production of Alfalfa Hay and Seed in Minnesota, 1930-1942

Year	Hay			Seed		
	Acres harvested	Yield, tons	Production, tons	Acres harvested	Yield, bushels	Production, bushels
1930	661,000	1.75	1,157,000	33,000	1.5	49,500
1931	727,000	1.50	1,090,000	33,000	1.3	42,900
1932	800,000	1.90	1,520,000	36,300	1.5	54,400
1933	824,000	1.50	1,236,000	54,000	1.5	81,000
1934	671,000	.85	570,000	29,000	1.3	38,000
1935	872,000	2.10	1,831,000	64,000	1.4	90,000
1936	1,046,000	1.45	1,517,000	108,000	1.5	162,000
1937	1,203,000	1.95	2,346,000	108,000	1.4	151,000
1938	1,263,000	2.00	2,526,000	92,000	1.0	92,000
1939	1,212,000	1.90	2,303,000	128,000	1.3	166,000
1940	1,224,000	1.85	2,264,000	168,000	1.0	168,000
1941	1,322,000	2.10	2,776,000	72,000	0.8	58,000
1942	1,441,000	2.20	3,170,000	48,000	0.9	43,000

state have been higher than these average yields for the entire state. Information obtained by the writer from sources considered reliable indicated that many farms in the northern part of the state averaged 6 to 8 bushels of alfalfa seed per acre until the early 1930's and a few went as high as 18 bushels per acre. Many seed growers stated that their seed usually provided a return of $75.00 to $100.00 per acre for the years preceding 1930.

Growers in these northern counties reported verbally, and the reports were checked through several sources, that alfalfa-seed crops in their counties have been less productive since 1930. From 1930 to 1937, crops were only intermittently good. The writer talked to a few growers who went out of alfalfa-seed production as early as 1933 because of seed failures. Some farms had good crops as late as 1939, but yields were far below those reported for earlier years. In 1940, the seed crop as a whole in these northern counties was reported a near failure. In 1941, seed set poorly in all the northern counties. The best alfalfa observed by the writer that year averaged about 4 bushels to the acre on one farm. Some second-cutting alfalfa might have produced more than 4 bushels per acre had it not been severely injured by frost. These reports are substantiated by the fact that the average yields per acre over the entire state for 9 of the 13 years from 1930 to 1942, inclusive, were below the 1919-1929 mean average.

By 1939 growers had formulated numerous theories to account for the reduction in seed yields. Some attributed it to grasshopper damage. During years when these complaints were received, grasshoppers were causing damage to other crops in some counties. Field men from the Minnesota State Entomologist's Office made grasshopper surveys and found these insects insufficiently numerous to be causing the extensive damage to alfalfa as reported.

Others attributed the reduction to thrips. Thrips commonly occur on alfalfa in Minnesota and feed on the flowers and stems by rasping tissues and sucking juices. Sorenson *(18)* observed some thrips damage to alfalfa flowers in Utah and suggested thrips were responsible for at least part of the alfalfa-seed reduction in that state. They do not cause more than a minor amount of the injury in Minnesota.

Some thought the reduced yields were due to conditions of soil and soil moisture, but experiments by the Agricultural Experiment Station in Beltrami and Koochiching counties indicate that any deficiency of nutrients is not the cause of the difficulty except to some extent on fields suffering from a sulphur deficiency. When fertilizers were applied to soils deficient in other nutrients, the vegetative growth was improved tremendously while the seed setting was apparently but little affected. It is true that chemically-deficient soils produce inferior alfalfa plants and these, in turn, yield inferior seed. On some of the best soil in northern Minnesota seed crops are often failures during the second or even the first year.

Weather was credited with the reduction of this crop by many. Most authors claim that adequate soil moisture, limited summer rainfall, and warm weather are factors conducive to good seed-set in alfalfa. The weather during the alfalfa-growing seasons for the years 1941 and 1942, the two years alfalfa seed-producing fields in northern Minnesota were under observation by the writer, was most unfavorable. In 1941 there were frequent rains and cool weather. The first killing frost was on August 27. In 1942 the last killing frost of late spring was on June 12 and the first killing frost of late summer was on August 24. The temperatures throughout the growing season were low and rainfall was abnormally high. In the writer's opinion, weather does lessen alfalfa-seed yield, but it is not responsible for successive seed losses over a period of years.

Many farmers placed the blame of seed failure on a scarcity of bees. They thought most bees were destroyed when peat was burnt off the land which they are now farming. In one of the more recent studies of insect tripping and pollination of alfalfa flowers and their relation to alfalfa-seed setting, Tysdal *(22)* suggests that failure of seed to set is sometimes due to an insufficient number of pollinating insects. These insects include leaf-cutting bees, which are also known as solitary or ground bees (*Megachile* species); honey bees (*Apis* species); bumble bees (*Bombus* species); and alkali or ground bees (*Nomia* species). This may be true in some sections of the country, but there is no obvious lack of tripping and pollinating insects in Minnesota. Bumble bees, ground bees, and others were numerous in alfalfa fields in Minnesota, even in fields which were thoroughly burnt-over in the spring of 1942. At present, the large-scale reduction of alfalfa-seed yield in this state cannot be explained through lack of pollination.

Density of plant growth was also given as a reason for the seed failures. Occasionally growers sowed alfalfa seed thin to test whether density of plant growth prevented development of seed. The result was usually disastrous since a rank growth of weeds soon overran the fields and the seed yield was not improved. It has been observed that dense alfalfa may set seed unless it lodges badly early in the season.

The occurrence of the alfalfa plant bug (*A. lineolatus* [Goeze]) in Minnesota during the early 1930's, with an increase in population intensity during the intervening years, is closely correlated with the reduction in the alfalfa-seed yield during this period.

Work initiated in 1939 to substantiate or disprove the opinion that this insect was causing damage demonstrated conclusively that *A. lineolatus* and other closely related mirids were responsible for much of the reduction in the alfalfa-seed yields.

Mirid Injury to Alfalfa

General field observations and preliminary cage studies revealed the feeding habits of *Adelphocoris lineolatus, A. rapidus,* and *Lygus* spp. These insects, when seeking food, puncture buds, flowers, and young pods with their piercing and sucking-type mouth parts. The resultant injury is thought to be mainly phytotoxic, which is explained more fully under histological studies, and usually causes the affected parts to wilt and die. In addition to injury to the reproductive structures, damage to a less noticeable degree is done to stems. In early spring, nymphs of *A. lineolatus* and *A. rapidus* feed on the sap of tender alfalfa stems and very likely cause some damage to them. These insects also cause oviposition injury to the stems.

The investigations discussed on the following pages were made to determine the extent of injury caused by these insects under controlled conditions and to confirm conclusions drawn from field observations.

METHODS AND MATERIALS

For the purpose of studying mirid injury to alfalfa, cylindrical cages (6″x10″) were constructed from 16-mesh wire screen to which muslin sleeves were added. These cages were supported over the alfalfa plants by means of wooden stakes to which they were attached.

Cage studies were conducted in the field at St. Paul in 1940-1941 and at Blackduck in 1941-1942 to determine the type and the extent of feeding injury under controlled conditions.

A. lineolatus was introduced into cages containing buds, flowers, pods, or vegetative structures of alfalfa. Similar studies were conducted for *A. rapidus* and *Lygus* spp. Also, *A. lineolatus, A. rapidus,* and *Lygus* spp. were caged with buds, flowers, pods, or vegetative structures of alfalfa to ascertain what their combined injury would be.

Healthy and apparently egg-free alfalfa stems were caged several days prior to the beginning of injury studies to allow a sufficient period for any previously injured reproductive parts to wilt or drop. At the end of the check period, the alfalfa plants were carefully examined and any wilted or wilting parts that had not already fallen were removed. The cages were again checked to be sure they were insect-free. A ratio of bugs to buds, to flowers, to pods, or to vegetative structures was established by removing from the cages any flower parts in excess of the ones needed to make the desired ratio.

Insects were collected from the field by means of a 12-inch insect-collecting net. They were drawn from the net into a cushioned aspirator to prevent injury and were introduced into cages in definite ratios to the number of buds, flowers, pods, or vegetative structures contained therein.

Various exposure times were used. At the end of these timed periods, the mirids were removed from the plants. It was necessary to remove the cages in order to be sure all the insects were released. The cages, now insect-free, were replaced over the alfalfa plants.

The plants were then observed for indications of mirid-feeding injury and records were kept.

The same procedure was used in setting up control cages as checks on the injury cages except, of course, no insects were ever introduced. At the end of the timed exposure periods, cages were removed from the control plants the same as from those with insect injury. This was done to eliminate the factor of possible mechanical injury to some plants and not to others. The cages were replaced and development was noted.

AUTOMATIC AND ARTIFICIAL TRIPPING OF ALFALFA

Untripped alfalfa flowers were caged free from insects at St. Paul, 1941, and were observed for self-tripping and pod development. Self-tripping was evidenced by the formation of seed pods from 5.4 per cent of the flowers. Results obtained are presented in table 2.

Although flowers were examined often, an actual count of pod set was made on the 19th day. All untripped flowers, and very likely some tripped flowers, had fallen by that time, leaving only early-stage pods. The number of self-tripped flowers was probably more than 5.4 per cent. Armstrong and White *(1)* found a much greater pod set on automatically tripped, "high pod-setting" alfalfa, but their figures for "low pod-setting" alfalfa corresponded closely with those of the writer. They also found that many self-tripped flowers failed to set seed.

Tripping is, in general, considered an essential prerequisite to pod-setting. Therefore, all flowers used in the insect-injury cages and in the control cages were artificially tripped and also cross-pollinated to insure a maximum of pod formation in all. The so-called tripping, or releasing of the staminal column from beneath the keel which encloses it, was accomplished by lightly pressing the keel with the tip of the handle of a small camel-hair brush. The staminal column consists of the pistil surrounded by 10 diadelphous stamens and the keel is formed by the fusion of

Table 2. Self-tripping and Pod Formation in Insect-free Cages St. Paul, Minnesota, July 27 to August 15, 1941

Flowers caged	Days observed	Flowers dropped	Flower fall	Pods formed	Pod set
			Per cent		Per cent
127	19	123	96.9	4	3.1
127	19	116	91.3	11	8.7
153	19	146	95.4	7	4.6
407		385	94.6*	22	5.4*

* Average.

the two lower petals. Flowers were cross-pollinated by brushing the pistil with pollen from flowers of other plants. Flowers tripped more readily on warm days than on cool days.

Only the required number of flowers to complete the desired bug to flower ratio was left on the plants. Ratios of 1 bug to 5 flowers, 1 to 10, and 1 to 15 were used.

FEEDING INJURY TO BUDS

Injury to buds of alfalfa is obvious a few days following feeding by the alfalfa insects. The normal green color fades and the buds turn yellowish and, from a short distance, appear almost white. The blasted parts die and usually drop to the ground within a week or more. Some fields have been observed in which most buds were dead and very few flowers were formed; these fields were heavily infested with mirids.

This phase of the cage study on mirid feeding is limited. Other cage experiments were begun but, due to unavoidable conditions, were not carried to completion. The extent of bud injury based on available data is indicated in table 3. Racemes of buds were taken as units since it was not practical to count the compactly arranged individual buds. There were approximately 30 buds per each raceme.

There was 100 per cent bud blast when buds were exposed as long as 10 days (240 hours) at different ratios of bugs to racemes. The per cent of bud blast was still high when the exposure was reduced to 48 hours at different ratios. The control cage for these showed a 14 per cent bud blast resulting from factors other than insects.

Table 3. Feeding Injury to Alfalfa Buds by *A. lineolatus*, *A. rapidus*, and *Lygus* spp., St. Paul and Blackduck, Minnesota, 1940-1941-1942

Species of Miridae	Exposure to bugs	Ratio Bugs : Buds	Total racemes of buds	Buds blasted
	Hours			Per cent
A. lineolatus	240	2 : 1	14	100.0
A. rapidus	240	1 : 1	19	100.0
Lygus spp.	240	1 : 3	45	100.0
A. lineolatus	48	1 : 1	62	60.0
A. lineolatus	48	1 : 2	196	61.0
Lygus spp.	48	1 : 2	50	40.0
Combined: *A. lineolatus*, *A. rapidus*, *Lygus* spp.	48	1 : 2	50	50.0
Control	None	0 : 125	125	14.0

FIG. 2. Left: Development of flowers from alfalfa buds in insect-free cage
Right: Development of flowers from alfalfa buds in cage with *A. lineolatus*
(48-hour exposure)
(White object in each picture is three inches long)

Figure 2, left, shows the extent of flowering 20 days after early-stage buds were caged free from insects. Forty-five racemes of buds were used. Figure 2, right, shows the extent of flowering 20 days after early-stage buds were enclosed with *A. lineolatus* which were allowed to feed for 48 hours at a ratio of 1 bug to 2 racemes. There were 36 racemes of buds.

FEEDING INJURY TO FLOWERS

Emphasis was placed on the role of mirids (*A. lineolatus, A. rapidus,* and *Lygus* spp.) as effectors of flower fall. Cage studies were supplemented by field observations.

Whenever possible a series of four cages was placed on a single alfalfa plant in order to prevent any variations which might result from genetic differences in alfalfa. One of the four cages was free from these insects and thus served as a check or control against the others.

The insects were collected from alfalfa by means of a net and an aspirator and were introduced into the cages. Adults and late-instar nymphs were encaged with the flowers; adults numbered 75 per cent of the total. The larger percentage of adults and nymphs encaged for aggregate feeding by *A. lineolatus, A. rapidus,* and *Lygus* spp. was *A. lineolatus* and *Lygus* spp. since these were far more numerous under natural field conditions.

Exposures were either 24 or 72 hours. Feeding-injury studies were carried out at St. Paul in 1941 and at Blackduck in 1942.

Only a single cage study of *A. rapidus* alone is included in these data. This species is less important, principally because of its lower intensity in this state, than either *A. lineolatus* or *Lygus* spp.

Table 4 is a summary of the mirid-feeding injury to alfalfa flowers. There is sufficient evidence to conclude that, in cage studies in the field, *A. lineolatus* causes more damage than the other species considered, either separately or in combination.

The per cent of flower fall was determined when young pods were developed to a point where they could be seen. This was usually a week after the bugs were removed from the cages but was sometimes as much as two weeks, depending on the time required for pod formation. All of the flowers which had fallen to the bottom of the cages and a few flowers which were dead but still attached to the plants were considered as flower fall.

When *A. lineolatus* was caged with flowers for a period of 24 hours at a ratio of 1 bug to 5 flowers, the flower fall noted approximately 8 days later was 89.67 per cent. When the number of flowers was increased so as to make ratios of 1 bug to 10 flowers or 1 bug to 15 flowers, the per cent of flower fall was reduced.

With the exposure period 72 hours instead of 24 hours, where *A. lineolatus* was encaged at ratios of 1 bug to 5 flowers and 1 bug to 10 flowers, there were flower drops of 98.22 per cent and 99.44 per cent, respectively.

Flower fall in the study of *A. rapidus* was 92.50 per cent at a ratio of 1 bug to 5 flowers exposed for 24 hours.

The flower fall in cages with Lygus bugs was less than with Adelphocoris bugs. The greatest amount of flower fall, 67.27 per cent, was at the ratio of 1 bug to 5 flowers when the exposure was 24 hours.

The cage studies indicate that the combined damage of *A. lineolatus, A. rapidus,* and *Lygus* spp. is less than the amount of damage caused by *A. lineolatus* or *A. rapidus,* but is more than the amount of damage caused by *Lygus* spp.

Table 4. Summary of Feeding Injury to Flowers by *A. lineolatus*, *A. rapidus*, and *Lygus* spp., St. Paul and Blackduck, Minnesota, 1941-1942

Species of insect	Exposure to bugs	Ratio Bugs : Flowers	Flowers caged (tripped)	Replica- tions	Flower fall				
					Total	Range		Average	Control cages*
	Hours					Per cent		Per cent	Per cent
A. lineolatus	24	1 : 5	755	151	677	93.60	86.21	89.67	42.63
	24	1 : 10	610	61	498	99.17	64.12	81.64	41.42
	24	1 : 15	600	40	377	72.22	53.33	62.83	36.68
A. rapidus	24	1 : 5	80	16	74	....	....	92.50	17.65
Lygus spp.	24	1 : 5	275	55	185	72.63	63.64	67.27	34.80
	24	1 : 10	400	40	254	73.75	55.38	63.50	38.32
	24	1 : 15	300	20	166	58.33	50.67	55.33	39.32
Combined: *A. lineolatus*, *A. rapidus*, *Lygus* spp.	24	1 : 5	525	105	385	87.59	64.29	73.33	31.27
	24	1 : 10	440	44	308	80.50	52.14	70.00	31.27
	24	1 : 15	315	21	175	60.00	51.11	55.56	31.27
A. lineolatus	72	1 : 5	225	45	221	100.00	96.84	98.22	47.06
	72	1 : 10	180	18	179	100.00	99.23	99.44	35.54
	72	1 : 15	165	11	137	100.00	76.67	83.03	35.54

* Control studies detailed in table 5.

Table 5. Summary of Data from Insect-free Cages Run as Controls for Bug Injury Cages, St. Paul and Blackduck, Minnesota, 1941-1942

Species for which control run	Ratio for which control run Bugs : Flowers	Flowers caged	Flowers dropped	
		Number	Number	Per cent
A. lineolatus	1 : 5	441	188	42.63
	1 : 10	338	140	41.42
	1 : 15	259	95	36.68
A. rapidus	1 : 5	68	12	17.65
Lygus spp.	1 : 5	273	95	34.80
	1 : 10	274	105	38.32
	1 : 15	295	116	39.32
Combined: *A. lineolatus*, *A. rapidus*, *Lygus* spp.	1 : 5	307	96	31.27
	1 : 10	307	96	31.27
	1 : 15	307	96	31.27
A. lineolatus	1 : 5	119	56	47.06
	1 : 10	121	43	35.54
	1 : 15	121	43	35.54

Data obtained from observations on tripped and cross-pollinated flowers in insect-free or control cages are in contrast to the data on mirid-infested flowers. They are presented in table 5. This table indicates the species of insect and the bug-flower ratio for which each control was run.

Seventeen control cages were operated, some of which served as checks on as many as three mirid-infested cages. It will be noted that the flower fall, while comparatively low in relation to the caged insect injury, is still high. Approximately 35 per cent (range, from 17.65 to 47.06 per cent) of the flowers dropped from the alfalfa plants even when the flowers were tripped, cross-pollinated, and caged free from insects. This being true, not all flower fall in bug-infested cages is attributable to mirid injury. It would seem then that the difference between the flower fall in bug-infested cages and the flower fall in control cages (mirid-free) would more nearly represent the actual damage resulting from mirid feeding (table 6).

When considered in this manner, *A. lineolatus* at a ratio of 1 bug to 5 flowers was responsible, after 24 hours' feeding opportunity, for 47.04 per cent flower fall. The per cent of damage decreased, though not proportionately, when there was a reduction in the number of bugs per flowers. This is similarly true of *Lygus* spp. and of *A. lineolatus, A. rapidus,* and *Lygus* spp. when considered together. Although the per cent of total flowers injured decreased when the exposure period was 24 hours, there was actually an increase in the number of flowers damaged by

Table 6. Probable Extent of Flower Fall Caused by Mirid Feeding

Species	Exposure	Ratio Bugs : Flowers	Flower fall in Mirid cages	Flower fall in Control cages	Probable flower fall by mirids	Flower fall per bug
	Hours		Per cent	Per cent	Per cent	
A. lineolatus	24	1 : 5	89.67	42.63	47.04	4.48
	24	1 : 10	81.64	41.42	40.22	8.16
	24	1 : 15	62.83	36.68	26.15	9.42
A. rapidus	24	1 : 5	92.50	17.65	74.85	4.62
Lygus spp.	24	1 : 5	67.27	34.80	32.47	3.36
	24	1 : 10	63.50	38.32	25.18	6.35
	24	1 : 15	55.33	39.32	16.01	8.30
Combined: *A. lineolatus*, *A. rapidus*, *Lygus* spp.	24	1 : 5	73.33	31.27	42.06	3.36
	24	1 : 10	70.00	31.27	38.73	7.00
	24	1 : 15	55.56	31.27	24.29	8.33
A. lineolatus	72	1 : 5	98.22	47.06	51.16	4.91
	72	1 : 10	99.44	35.54	63.90	9.94
	72	1 : 15	83.03	35.54	47.49	12.45

each insect (table 6) when the number of flowers was doubled or tripled and the number of bugs remained unchanged. At a ratio of 1 bug to 5 flowers all the flowers were likely visited and some were revisited by the mirids. When the ratio was 1 bug to 10 or to 15 flowers, the possibility of more flowers being visited and the amount of injury being substantially increased was amplified. The number of revisitations was probably reduced.

Lygus spp., at a ratio of 1 bug to 5 flowers, were responsible for approximately 70 per cent as much flower fall in cages as *A. lineolatus* at the same ratio; at a ratio of 1 bug to 10 flowers, for 63 per cent; and at a ratio of 1 bug to 15 flowers, for 61 per cent. *A. rapidus* cage studies indicate a high flower fall.

FEEDING INJURY TO ALFALFA-SEED PODS

In observation cages and in pod-injury cages, mirid adults and nymphs were seen feeding on young alfalfa-seed pods, especially when there were few buds and blossoms. The injured pods shriveled, turned brown, and usually dropped to the ground within a few days following the injury. When 55 young pods were subjected to *A. lineolatus* at a ratio of 1 bug to 5 pods for 120 hours, pod mortality was 94.6 per cent.

INSECT INJURY TO VEGETATIVE STRUCTURES

It would seem that insects capable of killing buds, flowers, and pods in the course of their feeding could also inflict severe damage to other parts of the plant.

Table 7. Effects of Mirid Feeding on Growth of Alfalfa, St. Paul, 1941

Species	Bugs caged	Stems caged	Exposure	Stem height at start	Stem height at end	Growth
			Days	Inches	Inches	Inches
A. lineolatus	24	3	24	12	12	None
A. lineolatus	15	3	24	12	12	None
Control (no bugs)	0	3	24	12	26	14
A. lineolatus	24	3	22	12	18	6
A. lineolatus	15	3	22	12	18	6
Control (no bugs)	0	3	22	12	22	10

Nymphs of *A. lineolatus, A. rapidus,* and *Lygus* spp. feed on the early growth stage of alfalfa with apparently little effect on the vegetative parts.

It was observed that alfalfa in several fields that were heavily infested with Miridae failed to bloom and the alfalfa stems grew tall and slender, assuming a "stringy" appearance.

When alfalfa plant bug *(A. lineolatus)* adults and some nymphs were caged with alfalfa at the ratio of 8 bugs to 1 stem or 5 bugs to 1 stem, the growth rate of the stems was obviously retarded. Some stems failed to grow in height over a period of 24 days of continual exposure to these insects, which decreased in number during the period since they were not replenished. Others attained a limited height in 22 days while stems in control cages free from insects developed best, as shown in table 7.

Some mechanical injury to plant tissue naturally results from oviposition in alfalfa stems. In addition to individual punctures made for each egg, the stem occasionally splits for several inches extending beyond the limits of the eggs. However, this injury to the plants in general seems of little importance as such, but could serve as a port of entry for possible plant pathogens.

ALFALFA FLOWER FALL UNDER NATURAL FIELD CONDITIONS

Alfalfa flowers were observed under natural field conditions (St. Paul, 1940-1941) to determine the approximate extent of flower fall. Alfalfa plants were selected at random and the mature, untripped flowers thereon were used. Buds, pods, and immature and wilted flowers were removed. Thirteen plants, having a total of 1,125 flowers (table 8), were examined at various times during this phase of the study.

Of the total flowers, 91.82 per cent dropped to the ground or shriveled without forming pods. It is probable that this high

Table 8. Fall of Alfalfa Flowers under Natural Field Conditions, St. Paul, 1940-1941

Untripped flowers	Date begun	Days observed	Flowers dropped	Flower fall
				Per cent
44	9/ 2/40	13	44	100.00
92	9/ 4/40	17	88	95.65
315	9/ 4/40	17	294	93.33
28	9/15/40	6	26	92.86
12	9/15/40	6	12	100.00
32	9/15/40	6	30	93.75
53	9/15/40	6	52	98.11
50	9/15/40	6	50	100.00
28	6/28/41	31	24	85.71
158	6/28/41	9	141	89.24
70	6/28/41	13	68	97.14
116	6/29/41	12	83	71.55
127	7/27/41	18	121	95.28
1,125			1,033	91.82*

* Average is total flowers dropped divided by total untripped flowers.

mortality is due to several factors of which mirid-feeding injury is foremost. *A. lineolatus* and *Lygus* spp. were abundant in the alfalfa fields; *A. rapidus* was found in small numbers.

Histological Studies of Alfalfa Flowers Injured by *A. lineolatus, A. rapidus,* and *L. oblineatus*

Histological studies were made on mirid-injured flowers to determine the nature of the injury.

PROCEDURE AND OBSERVATIONS

The initial stages of this investigation were conducted at Blackduck, Minnesota (Beltrami County), during the summers of 1941 and 1942. Alfalfa flowers in the field were enclosed in small insect-free celluloid cages several days prior to the time known species of Miridae were introduced. The flowers were checked at the end of this period to see that they were still developing normally.

Nymphs and/or adults of *A. lineolatus* (Goeze), *A. rapidus* (Say), and *L. oblineatus* (Say) were then introduced into the cages, usually with one to five of the injury-free flowers. They were allowed to remain in the cages for different periods of time. Observations were made to determine the extent of feeding and to ascertain what parts of the flowers were attacked.

The feeding was centered mostly on the basal area of the flower and particularly in the region of the ovary. The insects often fed from the sides of the flower, either through the calyx or just above it. Sometimes they fed at the base of the receptacle and occasionally they crawled to the open end of the corolla and extended the mouth parts downward into the region of the ovary.

The act of piercing the flower required only a few seconds. The head of the insect moved back and forth as the mandibular stylets pierced the plant tissues. The mandibles and the enclosed maxillae could be forced deep into the flower when the labium, which does not puncture the plant tissues, was pushed back. Liquid food could be extracted in this way. There was usually a slight movement of the head as feeding progressed. This movement was probably associated with a movement of the stylet tips as new food sources were being tapped. The insects sometimes fed for five or ten minutes without completely withdrawing the mouth parts from the plant tissues and sometimes they moved from one flower to another during the course of a few minutes.

In cages and in the open field, adults and nymphs of one or more species of Miridae often fed simultaneously on the same flower.

After the insects had been caged with the alfalfa for a known number of hours or after they were known to have fed on flowers, they were removed from the cages. Some of these flowers were preserved immediately; others were left to develop further injury and were then preserved.

Similar cages were placed over alfalfa reproductive parts which were never subjected to mirid injury. These served as controls.

PREPARATION OF FLOWERS

Plant tissues were fixed in Randolph *(13)* "Craf" fluid, F. A. A. (Formalin acetic alcohol), and Bouin's solution. The Craf schedule was used for the most part and was quite satisfactory. The tissues were left in Craf 24 hours, then washed and stored in 70 per cent ethyl alcohol until needed for sectioning and staining.

The laboratory phases of the histological study were completed in the technique laboratory of the Botany Department, University of Minnesota, where equipment and materials for this work were made available.

Ordinary methods were used in the infiltration with paraffin and in embedding the tissues.

Microtome sections 12 μ thick were prepared using a Spencer rotary microtome and were placed on slides serially and in chronological order. Sections, mostly sagittal and parasagittal and numbering from 4 to 20 depending on the cover slip size, were mounted on each slide.

A staining procedure, based on that described by Sass *(15)*, was employed in running the slides through the final stages. It was necessary to vary the time required for several of the solutions since not all tissues absorbed and retained the stains equally.

INSECT INJURY TO FLOWERS

Mirid injury to flowers is thought to be partly mechanical caused by the piercing mandibular stylets of the insects, but primarily due to a phytotoxic or toxiniferous substance which is secreted with saliva and which breaks down the cells.

Smith *(17)* showed rather conclusively that two "capsid bugs," (*Plesiocoris rugicollis* and *Lygus pabulinus*) of the family Miridae, related to the insects included in the present study, produced a chemical substance which damaged plant tissues. When salivary substance from these capsids was artificially introduced into apple leaves and fruit, the resulting injury was similar to that caused by the direct feeding of these insects.

Mirid injury to alfalfa flowers is localized. It spreads to cells surrounding the feeding punctures made by these insects and eventually to other parts of the injured flower, but it does not affect the raceme of flowers as a whole since abscission of the single flower occurs within a few days.

The cells around the feeding punctures die and disintegrate. In some flower-section series, the disintegrating areas, which stained deeply, could be traced microscopically through the ovary wall to the ovules.

The path taken by the mandibular stylets was not determined, but it is thought, from the appearance of the injury and considering the relatively large size of the insects with their strong mouth parts, that feeding is both inter- and intracellular.

Feeding punctures could not be seen but cells in the injured area absorbed stain more readily than others. The disintegrating cells were discernible in 18-hour injury where the necrotic tissue stained deeply. In sections made from flowers taken from control or mirid-free cages, no such injury appeared.

An injury-free section is shown in figure 3. Progress of injury is shown in figures 4, 5, 6, and 7 which are *A. lineolatus* injury within 2, 18, 48, and 84 hours, respectively.

A. lineolatus injury of two hours' duration appeared in the ovary wall of an alfalfa flower as shown in figure 4. The feeding

FIG. 3. Photomicrograph of alfalfa flower without mirid injury (X 32)

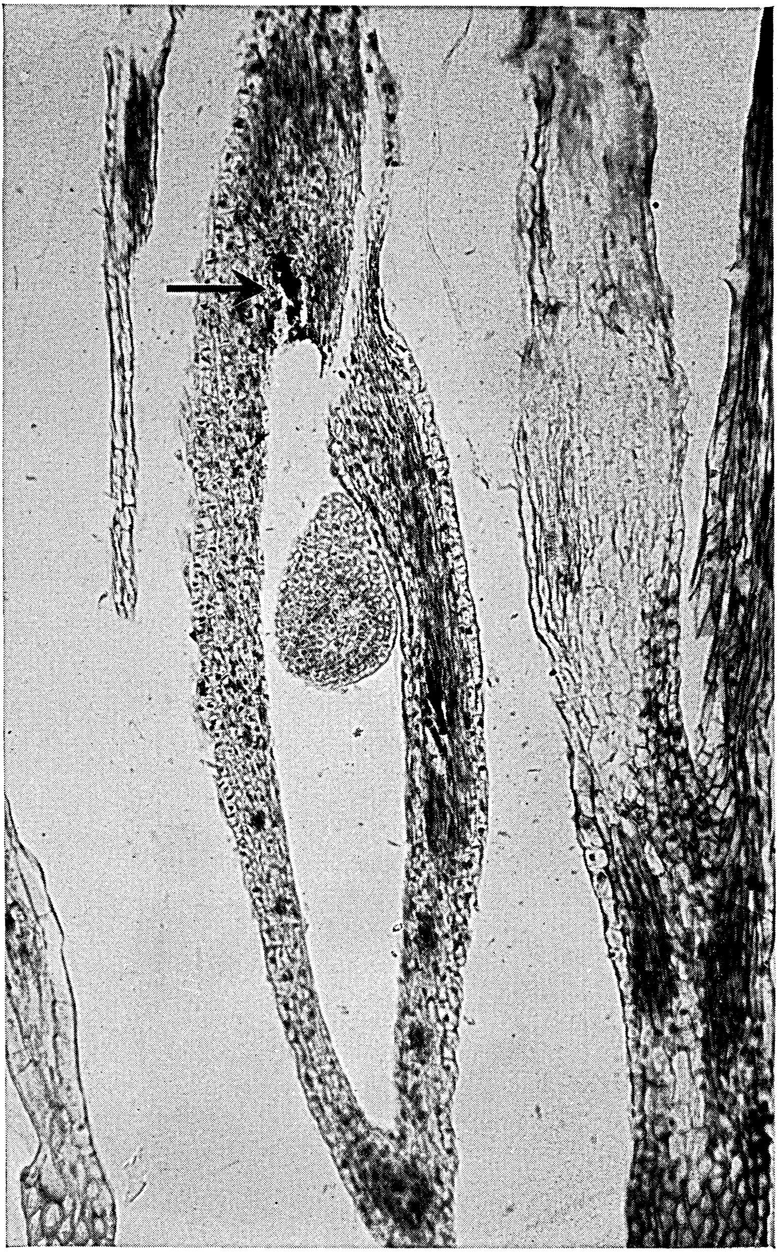

FIG. 4. Two-hour injury to alfalfa flower caused by *A. lineolatus* feeding (photomicrograph X 120)

punctures could not be distinguished but several cells in the immediate area of the injury reacted positively. These cells absorbed safranin to a much greater degree than those nearby and were apparently obstructed.

After 18 hours, injury initiated by *A. lineolatus* was in an advanced stage. Many cells of the ovary wall and of the ovules in the vicinity of the feeding punctures had disintegrated and others had collapsed, leaving the affected areas in a shriveled condition as shown by the dark-stained areas in figure 5.

Ovules had completely deteriorated in 48-hour *A. lineolatus* injury and the cells of the apical half of the ovary wall were necrotic and disorganized (figure 6). Vascular tissues in the base of the flower absorbed safranin to a large extent which suggests a corresponding spread of injury. In 84-hour *A. lineolatus* injury (figure 7), necrosis was still more advanced.

L. oblineatus causes damage to the ovary and ovules of alfalfa flowers in much the same way as *A. lineolatus*. *Lygus* damage, 6 hours after the insects fed on flowers, was in an early stage. There was a general necrosis of the affected cells of the ovary wall (figure 8) with shrinkage.

Eighteen-hour cell disintegration caused by *L. oblineatus* is pronounced in the ovary wall and in the ovules (figure 9).

Figure 10 shows 18-hour *A. rapidus* injury to the ovary and ovules of an alfalfa flower. Numerous openings in the ovary wall resulted from a breakdown of the cells in the proximity of the feeding punctures.

The breaking-down of the cells of the ovary and ovules resulting from mirid-feeding, as shown, causes many of the flowers to fall and thus contributes to the reduction in seed.

Carlson *(3)* published his findings on the relationship of *Lygus hesperus* Knight and *L. elisus* Van Duzee (Miridae) to alfalfa-seed production in Utah. He reported that the damage caused by these Lygus bugs to alfalfa buds and flowers is an important factor affecting alfalfa-seed production in that state.

Description of Miridae Studied with Special Reference to *Adelphocoris lineolatus* (Goeze)

The alfalfa plant bug, *Adelphocoris lineolatus* (Goeze)

MALE—Green or greenish-yellow tinged with brown; preserved specimens yellowish tinged with brown. Body elongate, sides nearly parallel, clothed with simple yellow pubescence.

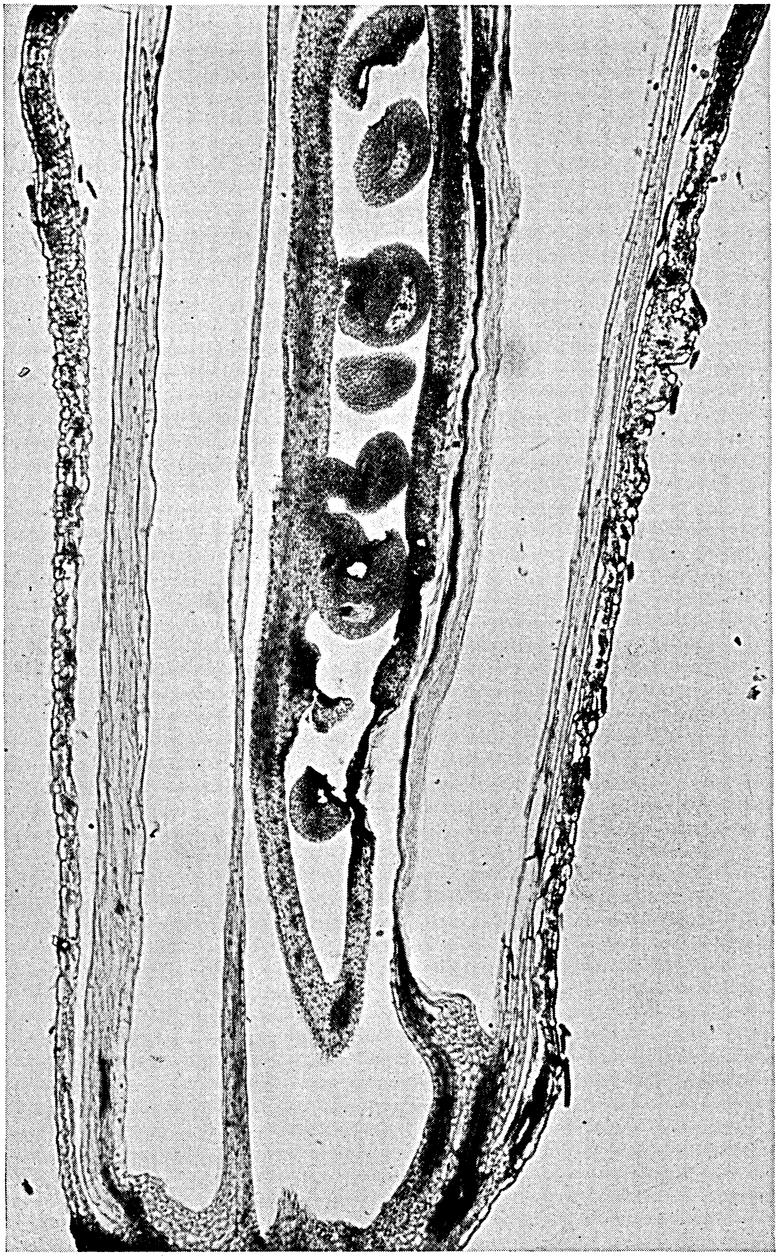

FIG. 5. Appearance of extensive necrosis of alfalfa ovary and ovules 18 hours after *A. lineolatus* feeding (photomicrograph X 55)

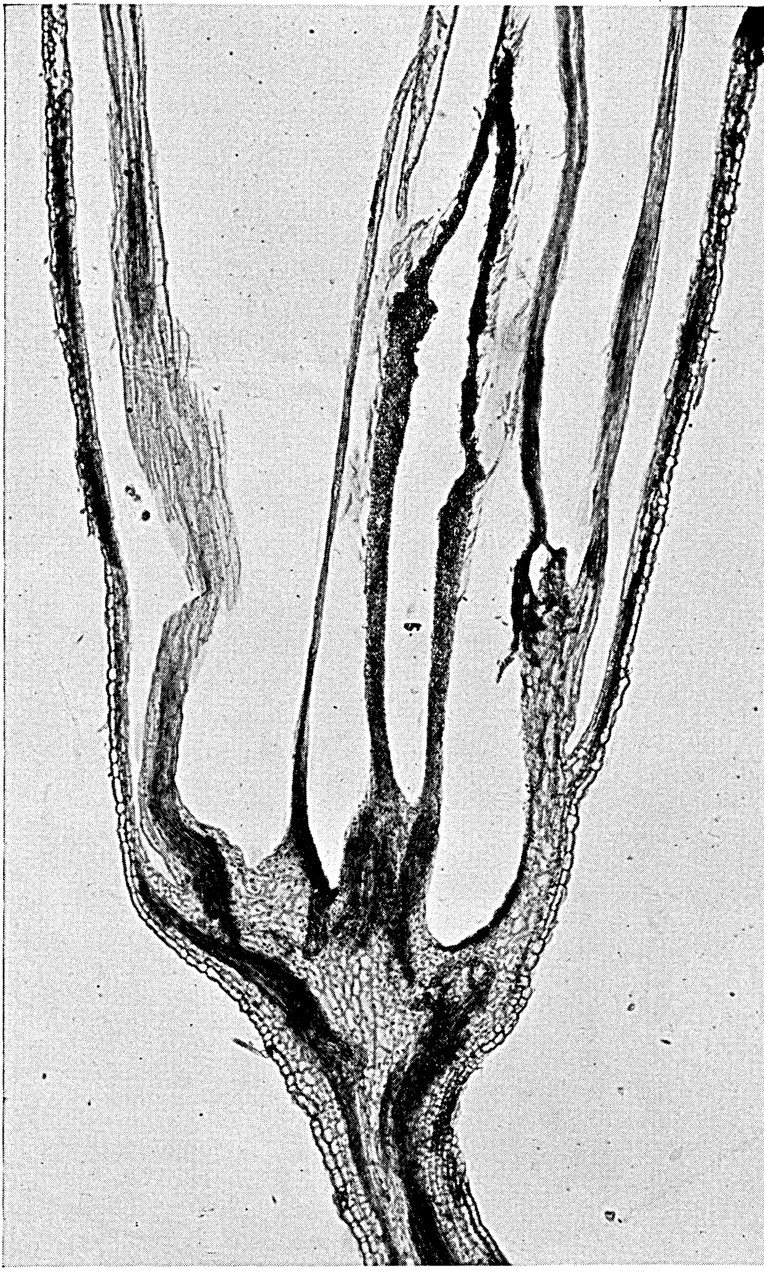

FIG. 6. Injury to alfalfa flower 48 hours after *A. lineolatus* feeding (photomicrograph X 55)

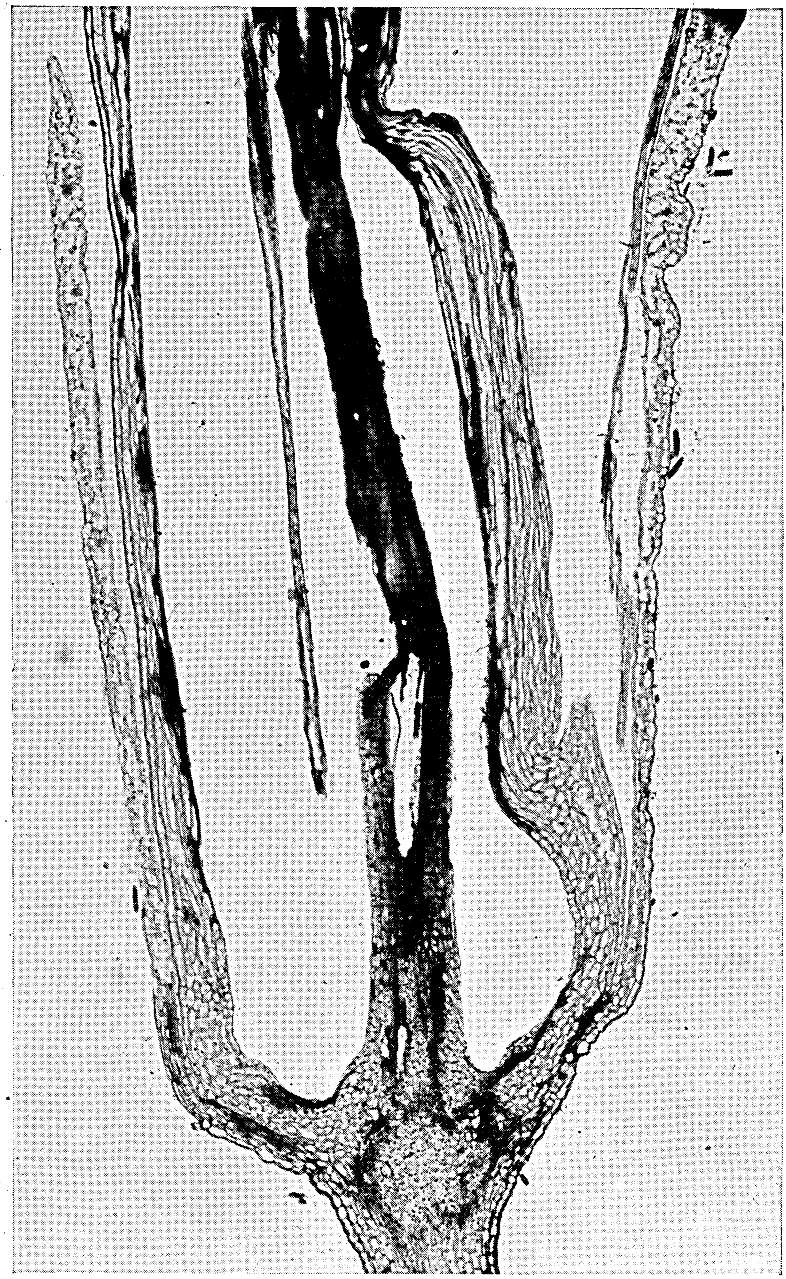

FIG. 7. Injury to alfalfa flower 84 hours after *A. lineolatus* feeding (photomicrograph X 55)

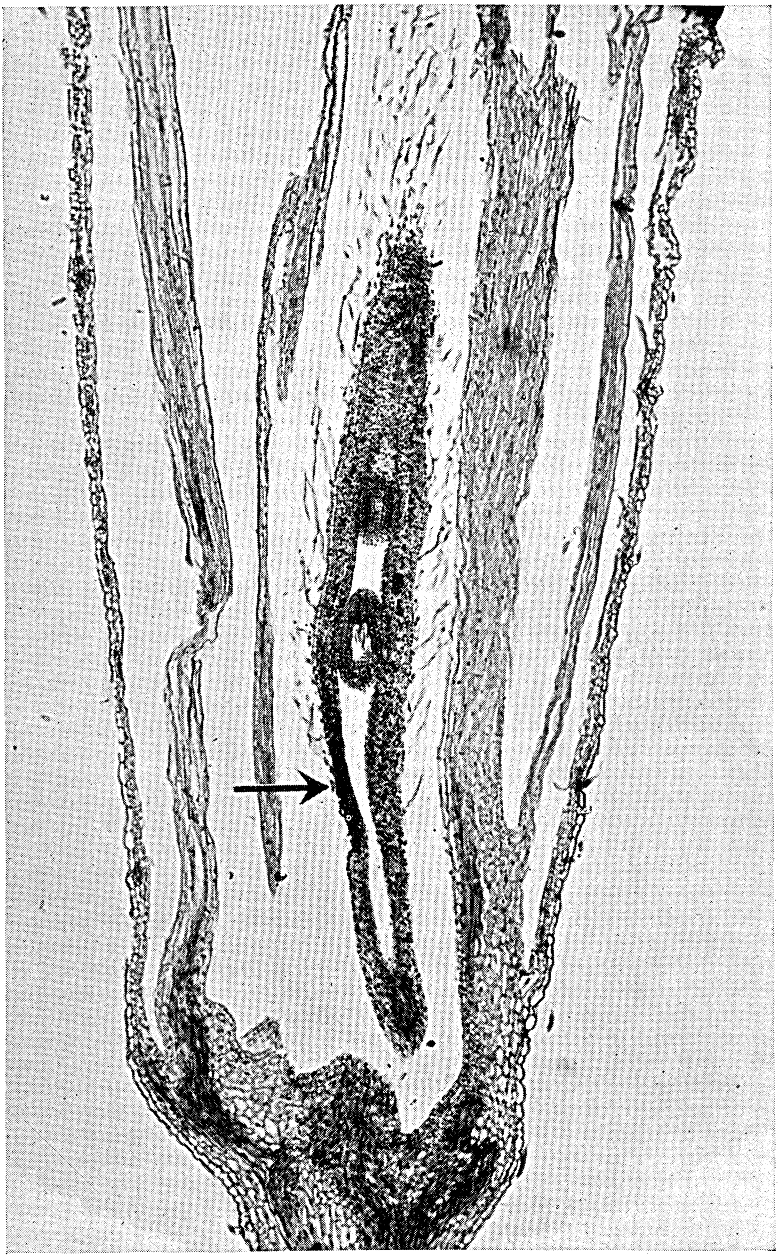

FIG. 8. Six-hour injury to alfalfa flower initiated by *L. oblineatus* (photomicrograph X 55)

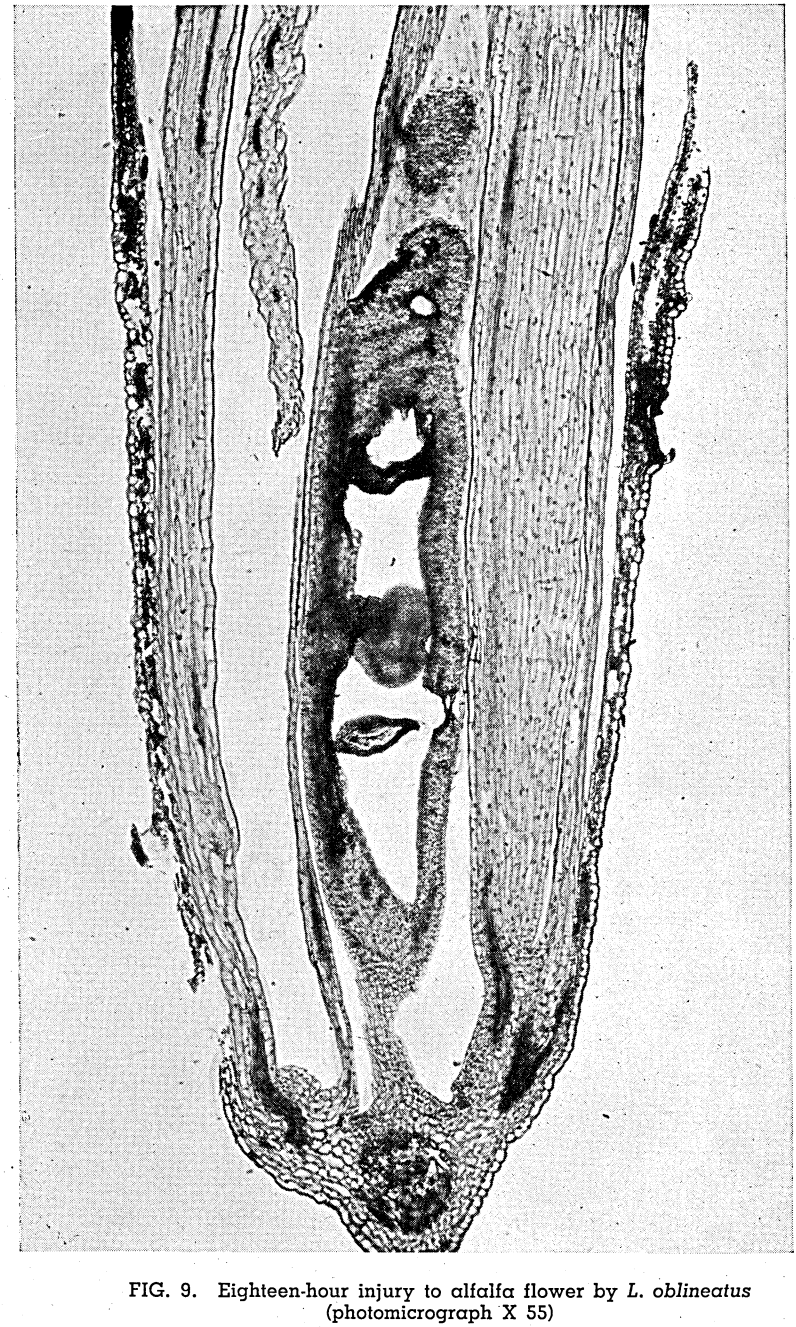

FIG. 9. Eighteen-hour injury to alfalfa flower by *L. oblineatus* (photomicrograph X 55)

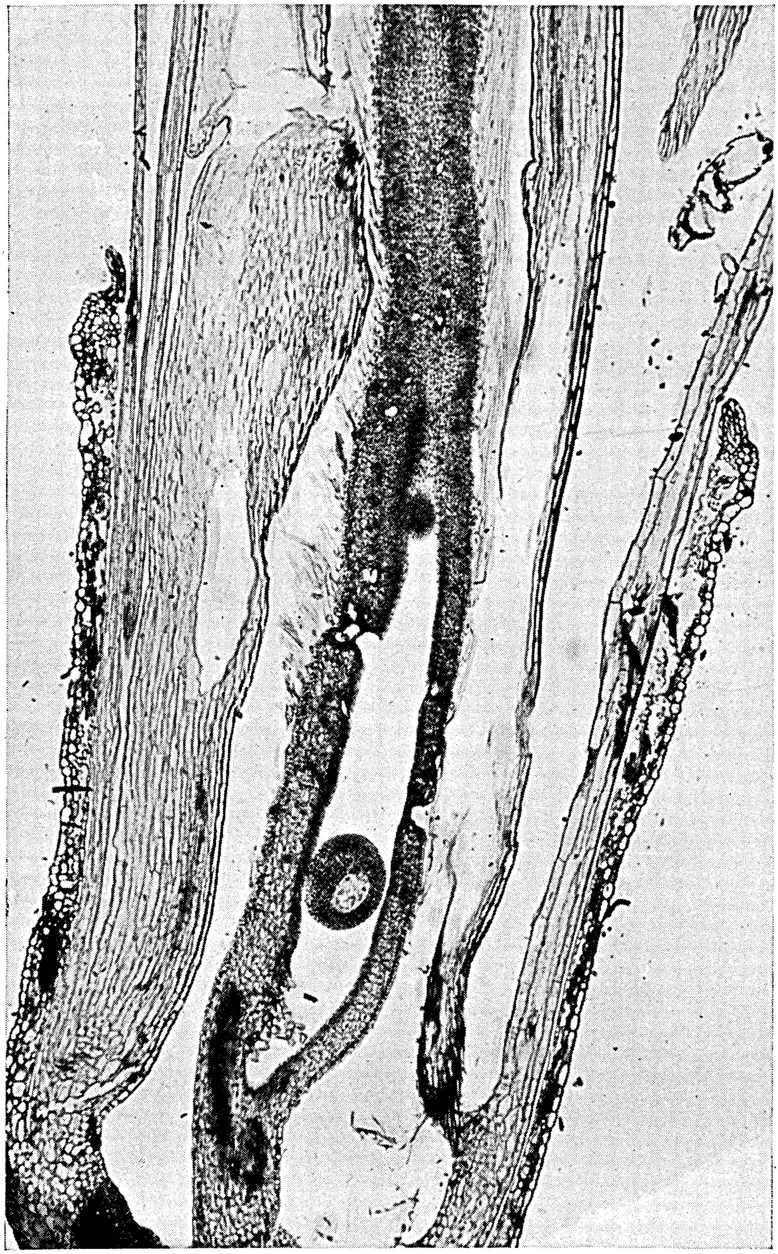

FIG. 10. Injury to alfalfa flower 18 hours after *A. rapidus* feeding (photomicrograph X 55)

Length 7.9—10.0 mm., width 2.8—3.5 mm. Head width 1.29, vertex 0.40. Antennae length I, 0.97; II, 2.74; III, 2.05; IV, 1.08. Antenna brownish-yellow at base, apical half reddish-brown, all segments densely clothed with dark inclined hairs. Proboscis four-segmented, length 2.79. Pronotum, length 1.20, width at base 2.27, often with two dark spots near base. Scutellum with two median longitudinal fuscous lines of variable intensity. Inner margin of clavus, apical half of corium, costal margin and membrane dark. Cuneus yellowish with fuscous mark inside. Legs brownish-yellow; black spots on femora arranged in rows anteriorly. Legs pubescent; tibia with black spines; tarsi brownish-yellow; claws black.

FEMALE—Body elongate, more robust than male. Length 7.4—9.0 mm., width 2.7—3.3 mm. Closely resembles male in coloration and form.

EGG—Length 1.36 mm., greatest diameter 0.33. Clear when first laid, yellowish when older. Slightly curved, thickest near base, compressed at apex and obliquely truncate.

FIRST INSTAR—Light green, tip of abdomen sometimes pink, anterior part of body and legs dusky. Eyes red. Length 0.99—1.86 mm. Elongate, narrow, sparsely clothed with short black hairs. Antennae stout, fourth segment red except base and apex. Wing pads absent.

SECOND INSTAR—Light green, tip of abdomen sometimes pink. Length 1.80—2.52 mm. Body elongate oval, sparsely clothed with black hairs. Antennae and eyes same as in first instar. Wing pads absent. Femora with black dots surrounding base of spines.

THIRD INSTAR—Light green. Length 2.43—3.24 mm. Body elongate oval, more densely clothed with short black hairs than first two instars. Fourth segment of antenna red and apical part of third sometimes reddish. Wing pads beginning to show. Tiny black markings on femora pronounced.

FOURTH INSTAR—Light green, anterior part and legs tinged with brown. Length 3.33—4.05 mm. Body oval, vestiture similar to that of third instar. Fourth antennal segment red, third and sometimes second, reddish-brown. Wing pads reach second abdominal segment. Femora and tibia with numerous black dots surrounding base of short black spines.

FIFTH INSTAR—Light green, fore part of body and legs dusky in older specimens. Length 4.32—6.3 mm. Body clothed with numerous small black hairs. Second, third, and fourth antennal segments similar to those of fourth instar but often darker. Wing pads well developed and reaching fourth abdominal segment, sometimes with tips brown. Color of femora and tibia similar to that in fourth instar but darker.

The rapid plant bug, *Adelphocoris rapidus* (Say)

Adelphocoris rapidus adults are similar to those of *A. lineolatus* in size and shape, but are strikingly different in color. Elytra dark brown with yellowish costal margins. Pronotum yellowish-brown, usually with two black spots near base. Head reddish-brown. First antennal segment, base and apical half of the second, dark brown; apical part of third and fourth reddish-brown.

Nymphs of *A. rapidus* can be distinguished from those of *A. lineolatus* by coloration. The first instar has abdomen, pronotum, head, and usually legs reddish; this color is more pronounced in later stages.

The tarnished plant bug, *Lygus oblineatus* (Say)

Lygus oblineatus is smallest of the mirids studied. It is approximately two thirds the length of *A. lineolatus*. The general color of the adult is brown mottled with yellow, blackish, and reddish-brown. Pronotum with elongate yellow lines. Scutellum has Y-shaped yellow area.

Biology of *A. lineolatus, A. rapidus,* and *Lygus* Spp.

SEASONAL OCCURRENCE

The two species of Adelphocoris bugs overwinter in the egg stage in Minnesota while the Lygus bugs, so far as is known to the writer, overwinter as adults. Some difference is noted in their seasonal occurrence for this reason.

Population counts of the adults and nymphs to show the peak population of each species in the field could have been made best in 1942 when the writer was located in Beltrami County. However, this was the year the control program, as detailed elsewhere in this bulletin, was conducted and it was impossible to get counts in untreated fields on enough consecutive days to establish specifically the dates when peak populations were attained by the three species.

There are two generations of *A. lineolatus* a year in Minnesota. Under natural field conditions, nymphs hatched from overwintered eggs of *A. lineolatus* by May 11 (1941) at St. Paul. The first adult appearance observed in the field was on June 10 and some of the females were ovipositing as early as June 22, which would indicate a preoviposition period of approximately 12 days. First-instar nymphs of the second generation were collected in the field July 9 and the first newly-emerged, second-generation adults—which were recognized as such by their light green color, their fresh appearance, and their inability to fly well—were collected in the net on July 29. Many of these second-generation adults were observed laying eggs in approximately two weeks. These were overwintering eggs.

All population records showed an overlapping of the various stages of the first and second generations. The peak of this overlapping (St. Paul, 1941) was in early August when adults and some late-stage nymphs of the first generation and nymphs of the second generation were in the field in large numbers.

Supporting evidence of the foregoing observations was obtained in 1942 at Blackduck, Minnesota (Beltrami County). There was a difference in occurrence dates; those of northern Minnesota were always later. The first adults appeared in the field at Blackduck June 23 and were not common until early July. Second-generation, first-instar nymphs were observed in limited numbers July 24 and second-generation adults did not appear until late August and early September. The last dates are based largely on cage studies.

The different stages of *A. rapidus* correspond closely to those of *A. lineolatus*.

Lygus spp. adults (males and females), which had overwintered as such, were swept from alfalfa as early as April 9 at St. Paul in 1941. First-instar nymphs were present in the field in early May and these reached the adult stage by early June. Adults and nymphs were present with the other mirids at all times but were not studied as thoroughly with respect to seasonal occurrence. There are two, and possibly three, generations each year in Minnesota.

FALL ACTIVITIES

The activity of all species is retarded on the cooler autumn days when the insects remain close to the ground for protection, but it is renewed on the occasional warm and sunny days of fall. The voracious appetites of the insects abate late in the season when the mean daily temperatures are lower. Most adult activity of *Adelphocoris* spp. is then confined to laying overwintering eggs in the less-succulent alfalfa stems near the ground.

The adults and the remaining second-generation, fourth- and fifth-instar nymphs of *A. lineolatus* and *A. rapidus* die with the approach of colder weather. Only the overwintering eggs remain.

Lygus spp. adults and nymphs seek shelter under leaves, dead plants, and other debris in fields where they begin hibernation. Only the adults are known to survive here.

All species have been collected from alfalfa and sweet clover at St. Paul as late as October 20.

OVERWINTERING

Cloth-covered frame cages (3′x2½′x2′) were arranged over flowering alfalfa plants in the field at University Farm, St. Paul, in late September, 1940. Several hundred adults and nymphs of *A. lineolatus* and *A. rapidus* were caged separately to check on overwintering. Leaves, loose soil, small piles of hay, and crowns of alfalfa plants provided possible sources of shelter in the cages.

Bug activity in the cages consisted mainly of oviposition.

The stems with the eggs of the known species were labeled and left to overwinter. Heavy snows in mid-November sifted through the cloth, which was already weakened by summer weathering, and covered the ground within the cages sufficiently to provide additional insulation from sub-zero weather. The cages were recovered with new cloth in early spring to prevent the escape of any adults or nymphs which might have overwintered.

Examination of these cages in March, April, and early May (1941) revealed that no adults or nymphs had survived. These results were substantiated in the spring of 1941 when samples of insect populations were swept from alfalfa and other plants near the cages and from other fields. In no instance has an overwintering adult or nymph of these two species been collected or seen by the writer.

In addition to *A. lineolatus* and *A. rapidus* eggs in the large overwintering cages, many others were laid in alfalfa stems in smaller cages which were set up in the fall. Stems containing these eggs were carefully labeled as to species and left in the field in large cloth-covered cages during the winter months.

Pieces of marked stems containing overwintered mirid eggs were taken to the laboratory to observe emergence of the nymphs. The stems and eggs were kept at approximately 23° C. in covered pint glass jars where a high relative humidity was maintained. Daily observations were made. Eight nymphs of *A. lineolatus* emerged April 25 in the laboratory and numerous others emerged during the following three weeks. *A. rapidus* nymphs emerged first on April 28 in the laboratory. Nymphs had less difficulty in emerging when the humidity in the jars was high and the stems and eggs were somewhat softened by it.

SPRING ACTIVITIES

The first nymphs of *A. lineolatus* and *A. rapidus* collected in the field in 1941 were taken at St. Paul, May 11, from alfalfa. They were active and moved about the alfalfa plants feeding on new tender shoots until the buds and flowers formed, then the growing nymphs moved to these preferred parts. Mirid nymphs as a whole migrate very little; this was shown in 1942 control studies. In mid-June they had moved only a few feet from their winter hosts.

Adults of *Lygus* spp. which had spent the winter in this stage were swept from alfalfa at St. Paul on April 9, 1941, and were, no doubt, active even earlier. Oviposition activities were not noted; however, first-instar nymphs were on the alfalfa in early May.

SUMMER ACTIVITIES

Adults and nymphs of all three species of mirids are active during the summer. They are more active on warm, sunny days than on cool ones and are most active from about 10 a.m. to 7 p.m. Their feeding, oviposition, and movements under natural field conditions are best observed at this season of the year. Mating of *A. lineolatus, A. rapidus,* or *Lygus* spp. was never seen.

MIGRATION

There is little doubt that adult insects are capable of traveling many miles in a few years or even in a single season as evidenced by the spread of *A. lineolatus* from Ames, Iowa, which Knight *(10)* considered as its probable center of distribution in the United States, to Minnesota and several surrounding states, as well as to the province of Manitoba.

The adults are active in the field and fly readily when disturbed, although seldom for more than 20 feet and usually only 5 or 6 feet to other alfalfa plants. They remain moderately close to the alfalfa when in flight and are difficult to see since their greenish-yellow color blends with the green of the foliage.

They can scarcely be considered strong fliers, yet they may be carried by winds and, in addition, are sometimes transported long distances in hay as eggs and lesser distances as nymphs or, possibly, adults. But the spread is probably due more to a gradual migration than to anything else. Scarcity of food and absence of shelter from the sun's rays seem to be the greatest stimuli in mass movement. When alfalfa is cut from a portion of the field or the buds and flowers are killed by these insects, there is a general movement to other alfalfa where food and shelter are available. This was true in fields observed at St. Paul and in northern Minnesota. A definite and proportionately large increase in mirid population in uncut alfalfa nearly always followed the harvesting of adjacent alfalfa.

The gradual movement of numerous bugs was especially noted in some alfalfa-seed fields which were burnt-over in the spring to destroy overwintering insect stages. Unburnt areas in these fields often served as centers of infestation. Large populations which built up at these points often destroyed buds and blossoms by early July and started moving to more favorable situations. The bug intensity at the periphery of the unburnt spots was often several times greater than elsewhere in the field. In Beltrami County, June 10, 1942, the *A. lineolatus* population in the center of a half-acre unburnt part of an alfalfa field was only 9 in 50 sweeps with an insect net; at the edge of the same area it had increased to 88; while at the edge of the adjacent alfalfa, which had been relatively free from Miridae due to thorough burning-over of the field in April and which was in full bloom, there were 348 specimens of *A. lineolatus* in 50 sweeps.

When abundant food and shelter are available for these insects, migration even within a field is not extensive until late June and early July after winged adults appear.

NIGHT FLIGHT OF *A. LINEOLATUS*

There is some movement of all three species of mirids at night; however, complete records were taken only for *A. lineolatus*.

During the period from June 30 to September 7, 1940, when observations of this type were made, 409 adults were attracted to the University light traps at St. Paul. Of this number 363 were males while only 46 were females. A possible explanation for this ratio may be that females are heavier since they contain numerous eggs and are, therefore, less able to fly. On numerous occasions gravid females in the field could scarcely fly from one alfalfa plant to another. The lowest number attracted to the light traps in a single night was 1 while the highest was 26.

Life History Studies of *A. lineolatus, A. rapidus,* and *L. oblineatus*

The life history studies of *A. lineolatus* and *A. rapidus* were begun in 1941 at St. Paul and those of *A. lineolatus* were continued at Blackduck (Beltrami County) the summer of 1942. Similar studies were conducted for *L. oblineatus* at Blackduck in 1942. No attempt was made to employ large numbers in either the study of *A. rapidus* or of *L. oblineatus* because their life histories are well known. Emphasis was placed on *A. lineolatus* instead since it is relatively new to the western hemisphere and as no extensive work on its life history and habits has been published here.

St. Paul weather data used in this study were taken from Climatological Data (Minnesota Section), U. S. Weather Bureau *(24)*, recorded at the St. Paul airport. Blackduck weather records were supplied by the Forest Ranger's Station at Blackduck, Minnesota, Division of Forestry, Department of Conservation, State of Minnesota.

METHODS AND MATERIALS

Life history studies were begun by selecting alfalfa for oviposition and rearing studies. The alfalfa stems were minutely examined to be sure there were no mirid eggs already present. Then 16-mesh, cylindrical screen cages (6″x10″) and celluloid cages (3″x6″) with fine-mesh cloth sleeves at both ends (large cages, figure 11) were placed over the plants some 10 days before known species of Miridae were to be introduced. At the end of this approximate 10-day period, all stems were again checked for any indication of mirid eggs.

Cages used for oviposition were the small celluloid cages (3″x6″) with the fine-mesh cloth sleeves at both ends and small celluloid cages (1″x3″) with cloth sleeves at one end and cork stoppers at the other. All celluloid cages were supplied with cloth windows to facilitate ventilation.

These small celluloid cages were used to enclose separate stems or grouped stems of the alfalfa plants which had been checked mirid-free. Each cage was labeled to show cage number, species to be contained therein, and date of oviposition.

The adult males and females were swept from the field in an insect net and collected from the net into an aspirator. Then they were introduced into the prearranged cages and allowed to remain for approximately 24 hours before they were removed. This was a satisfactory method of getting eggs. The eggs were confined to a relatively small area of the stems and were, therefore, easy to find.

The eggs were left to incubate in these cages and were observed carefully for any emergence of nymphs.

Other 1"x3" celluloid cages were used for the observance of nymphal development. They were arranged in series over alfalfa buds and flowers and were suspended from a cord between two stakes as shown in figure 11.

When the nymphs emerged, they were placed separately in these small rearing cages. The food supply was replenished if needed by transferring the nymphs to other flowers. Observations were made daily by removing the cork stoppers from the ends of the cages. After the nymphs passed from one instar to another, the exuviae were removed by means of a small camel-hair brush and the lengths of the stadia were recorded.

All data pertaining to these oviposition and nymphal developments were carefully recorded and eggs, nymphs, and adults were preserved in Hood's solution or 70 per cent alcohol for further study.

An excellent cage for making observations on oviposition,

FIG. 11. Rearing cages used in life history studies

feeding, and similar studies, without greatly disturbing the insects, is a cloth-covered, collapsible frame structure (3'x2½'x2') provided with three sleeves. These sleeves make it possible to see inside the cage and to have freedom for the arms and hands. This collapsible cage was designed by Dr. A. A. Granovsky, Division of Entomology and Economic Zoology, University of Minnesota, who supplied several for use in this work.

OVIPOSITION

A. lineolatus confines most egg-laying to alfalfa and sweet clover. However, when sexually mature females were confined in small cages containing stems of red clover (*Trifolium pratense* L.), timothy (*Phleum pratense* L.), soybeans, hedge bindweed (*Convolvulus* sp.) or pigweed (*Amaranthus retroflexus* L.), eggs were laid in each in the same manner as in alfalfa.

A. lineolatus females were frequently seen in the act of oviposition. Long periods of watching revealed that the eggs were most often laid in the early evening during midsummer, while the time of day seemed of little significance in late summer. In early summer the eggs were deposited in the stems a foot or more above the ground, but the eggs left for overwintering were placed closer to the stem base. The insects seemed to choose the older and less succulent growth in late summer, possibly because it provided more protection for the overwintering eggs.

When in the process of laying eggs, the female moves slowly along the stem with the tip of the labium close to the epidermis of the plant until a desirable place is found. Here the insect stops and apparently makes a shallow puncture in the stem with her mandibular stylets or bristles. Then she moves forward far enough to bring the caudal end of the body near the point "sampled." The body is arched and the ovipositor is extended from the sheath on the ventral surface of the abdomen until the apex is placed on the minute puncture previously made with the mouth parts. The ovipositor is inserted into the plant tissue and a single egg is deposited. The plant tissue is occasionally too tough and the ovipositor is withdrawn and the insect moves forward. This oviposition act, requiring approximately 45 seconds, is repeated for each egg that is laid.

The eggs are laid closely together in groups or rows and approximately 10 to 30 are laid in a 24-hour period. The eggs are so minute it is difficult to see them. The egg caps protrude slightly above the epidermis of the plant and appear as tiny

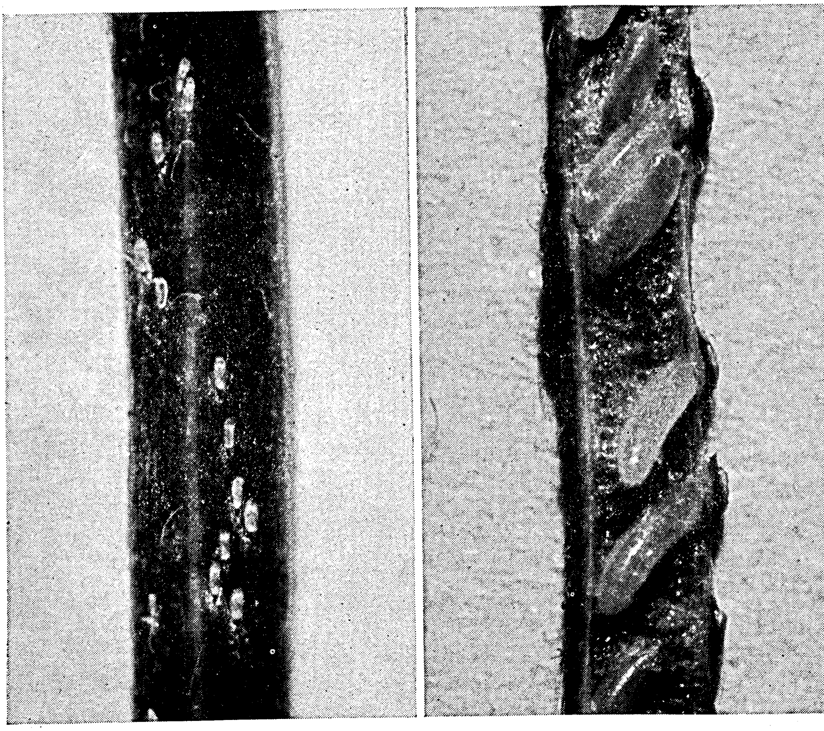

FIG. 12. Left: External view of eggs of *A. lineolatus* (Goeze) in alfalfa stem (photomicrograph approximately X 14)
Right: Internal view of alfalfa stem with *A. lineolatus* (Goeze) eggs (photomicrograph approximately X 14)

specks to the naked eye (figure 12—left). In figure 12, right, is shown a longitudinal section of an alfalfa stem with a characteristic arrangement of the eggs within the stem.

Gravid females of *A. lineolatus*, collected during 1940, 1941, and 1942 (table 9), were dissected to determine the approximate number of eggs. All insects examined contained eggs. The

Table 9. Eggs Dissected from *A. lineolatus* Gravid Females, 1940, 1941, 1942

Date	Females dissected	Eggs per female (mean)
July 3, 1940	2	27.0
August 11, 1940	2	31.5
September 16, 1940	4	18.5
June 24, 1941	5	23.2
July 11, 1941	5	16.6
July 27, 1941	1	18.0
July 29, 1941	2	33.0
July 31, 1941	1	25.0
August 25, 1942	4	46.2

maximum number per female was 56, August 25, 1942; the minimum was 3, June 24, 1941.

A. rapidus and *L. oblineatus,* especially the latter, have many host plants and may oviposit in a number of them although they are most common in alfalfa and sweet clover in Minnesota. The egg-laying habits of *A. rapidus* are essentially the same as those of *A. lineolatus.* In cage experiments, *L. oblineatus* frequently oviposited in irregular rows along the internodes of alfalfa plants.

INCUBATION

The eggs used in life history studies were obtained from oviposition cages in order that the species of insect and the dates the eggs were laid would be known.

Temperature has a bearing on the length of the incubation period. Therefore, records for *A. lineolatus* at St. Paul, 1941, were dealt with in three groups according to the dates the eggs were laid. The first group of eggs was laid over a period of 5 days, June 25-June 29, inclusive; the second group, 3 days, July 6-July 8, inclusive; the third group, 1 day, July 21. In the first two groups there is very little difference between mean days (15.03 and 15.44) and very little difference in mean temperatures (72.82 and 73.68). In the third group where the mean temperature is nearly 10 degrees higher, the mean number of days for incubation is lower (11.5). Conversely, where the mean tempera-

Table 10. Incubation Studies of *A. lineolatus, A. rapidus,* and *L. oblineatus,* St. Paul and Blackduck, Minnesota, 1941-1942

Developmental period	Nymphs hatched	Incubation period		Weather conditions during incubation period			
		Range	Mean	Mean temperature—°F.			Precipitation
		Days	Days	Maximum	Minimum	Average	Inches
A. lineolatus							
St. Paul—1941							
6/25-7/16	66	13-17	15.03	83.09	62.55	72.82	.118
7/6-7/24	78	14-17	15.44	84.95	62.42	73.68	.102
7/21-8/2	8	11-12	11.50	95.00	72.15	83.58	.015
Blackduck—1942							
7/25-8/14	82	15-20	17.72	74.76	56.33	65.55	.124
A. rapidus							
St. Paul—1941							
6/29-7/24	72	13-17	15.50	84.35	62.23	73.29	.093
L. oblineatus							
St. Paul—1941							
7/13-7/24	12	11-11	11.00	87.08	63.42	75.25	.089
Blackduck—1942							
7/27-8/12	34	14-16	14.50	74.29	55.47	64.88	.087

ture was only 65.55° F. as at Blackduck, 1942, eggs developed in 17.72 mean days.

Only one group of *A. rapidus* was incubated; this was at St. Paul in 1941. The mean temperature (73.29) and the mean days (15.5) closely correspond to those of the first two groups of *A. lineolatus* at St. Paul.

Similar records were kept for *L. oblineatus* at St. Paul, 1941, and at Blackduck, 1942. Eggs for each group were laid in one day. At St. Paul, *L. oblineatus* eggs required 11 mean days to develop at a mean temperature of 75.25° F. At Blackduck, this species hatched in 14.5 mean days at a lower mean temperature of 64.88° F.

The total number of all specimens hatched was 352.

The foregoing is summarized in table 10.

At the end of the incubation period nymphs worked their way from the egg coats which remained in the alfalfa stem. The anterior part of the insect's body was first to appear. Usually, the act of emergence was completed within 10 or 15 minutes and the nymphs moved about actively very soon. Different degrees of emergence of *A. lineolatus* nymphs from an alfalfa stem are shown in figure 13.

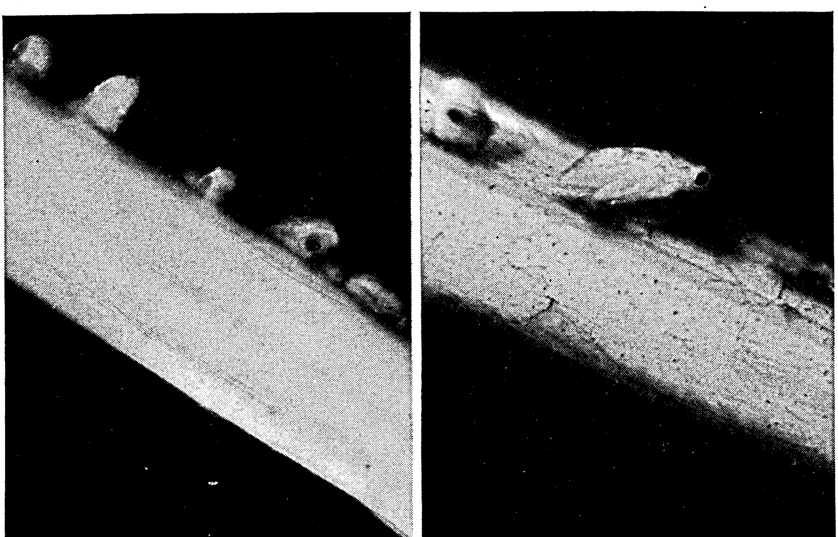

FIG. 13. Left: *A. lineolatus* nymphs beginning to emerge from alfalfa stem (photomicrograph approximately X 17)

Right: *A. lineolatus* nymphs emerging from alfalfa stem; one nearly free (photomicrograph approximately X 17)

NYMPHAL DEVELOPMENT

Life history studies were begun with three groups of *A. lineolatus* eggs oviposited at St. Paul in 1941 and one group oviposited at Blackduck in 1942. The first group had completed its life cycle in early August, 1941, the second group was in the fifth instar, and the third group had just completed incubation. These studies were discontinued at that time in order that the writer might accompany Dr. C. E. Mickel on an inspection trip to the northern Minnesota alfalfa seed-producing fields.

The *L. oblineatus* study began with one group for St. Paul (1941) and a second group for Blackduck (1942). The St. Paul study of *L. oblineatus* was discontinued after oviposition and incubation records were made.

Eliminating altogether the third group of *A. lineolatus* (St. Paul, 1941) and the first group of *L. oblineatus* (St. Paul, 1941), the nymphs of the remaining incubated eggs of the three species of Miridae, namely, *A. lineolatus, A. rapidus,* and *L. oblineatus,* were watched closely for nymphal stadia. These data are summarized in table 11. The weather was probably the determining factor in the length of time required for successive instars to emerge.

The mean developmental period of the five instars of *A. lineolatus* (first group) was 18.47 days at St. Paul in 1941 where the mean temperature for the period was 79.28° F. The mean developmental period of *A. lineolatus* at Blackduck in 1942 was 28.30 days at a mean temperature of 62.74° F. It will be noted, however, that in addition to the usual temperature difference between St. Paul and Blackduck, the *A. lineolatus* records for Blackduck (1942) were made from mid-August to mid-September, whereas records for the first group of *A. lineolatus* for St. Paul, 1941, were made from early July to early August. This, undoubtedly, accounts for the wide variance in developmental time requirements. A comparison of the data for the individual instars of *A. lineolatus,* St. Paul, 1941 (2 groups), and of *A. lineolatus,* Blackduck, 1942, indicates in every instance that a higher mean temperature brought about a shorter nymphal period.

Within the species the first and last nymphal stadia of each group of *A. lineolatus* were longer than the others. The longest time required for a single stadium of this species was 9.00 mean days for the fifth stadium at Blackduck, 1942.

The developmental period of *A. rapidus* for St. Paul, 1941, for all five instars was comparable to that for *A. lineolatus* at St. Paul,

Table 11. Time Required for Nymphal Development of *A. lineolatus*, *A. rapidus*, and *L. oblineatus*, St. Paul and Blackduck, Minnesota, 1941-1942

Developmental period	Instar	Nymphs	Nymphal period		Weather conditions during developmental period			
			Range	Mean	Mean temperature—°F.			Precipitation
			Days	Days	Maximum	Minimum	Average	Inches
A. lineolatus, St. Paul, 1941								
7/9-7/21	1st	17	4- 7	4.94	82.00	59.77	70.88	.117
7/14-7/26	2nd	17	1- 8	2.88	89.07	65.53	77.31	.082
7/17-7/31	3rd	13	2- 5	2.54	92.53	68.60	80.57	.06
7/20-7/30	4th	9	2- 4	3.22	95.54	71.45	83.50	.011
7/23-8/3	5th	9	4- 6	4.89	95.42	72.83	84.13	.007
			Total	18.47	Mean average		79.28	
A. lineolatus, St. Paul, 1941								
7/21-7/28	1st	40	2- 5	3.08	97.75	72.75	85.25	.015
7/23-8/1	2nd	30	1- 6	2.33	95.80	73.00	84.40	.009
7/25-8/3	3rd	26	1- 5	2.50	94.10	72.40	83.25	T
7/28-8/3	4th	12	2- 4	3.00	93.00	71.71	82.36	.002
All nymphs preserved before adults emerged.								
A. lineolatus, Blackduck, 1942								
8/11-8/21	1st	42	3- 8	5.31	74.64	54.82	64.73	.076
8/14-8/26	2nd	36	2- 6	3.80	71.62	52.15	61.88	.092
8/19-9/1	3rd	30	3- 7	5.10	72.29	56.43	64.36	2.635
8/23-9/4	4th	23	3- 7	5.09	68.15	52.54	60.35	2.861
8/27-9/14	5th	19	6-14	9.00	71.26	53.47	62.37	.196
			Total	28.30	Mean average		62.74	
A. rapidus, St. Paul, 1941								
7/13-7/27	1st	13	2- 6	3.85	89.00	65.53	77.27	.071
7/18-8/1	2nd	12	1- 5	2.42	93.07	69.20	81.13	.013
7/20-8/1	3rd	10	1- 3	1.80	95.08	71.15	83.12	.015
7/23-7/31	4th	5	2- 4	3.00	96.11	73.56	84.83	.01
7/26-8/1	5th	3	3- 5	4.33	93.43	72.00	82.71	.012
			Total	15.40	Mean average		81.81	
L. oblineatus, Blackduck, 1942								
8/10-8/18	1st	8	3- 8	5.75	72.33	52.78	62.56	.096
8/13-8/24	2nd	6	2- 6	4.17	72.50	52.08	62.29	.070
8/18-8/27	3rd	6	3- 5	3.83	71.80	53.80	62.80	.055
8/21-8/30	4th	5	3- 6	5.00	71.40	55.80	63.60	.209
8/27-9/7	5th	5	7-10	9.00	70.42	53.33	61.88	.28
			Total	27.75	Mean average		62.62	

1941, except the time for *A. rapidus* was 3 plus mean days less and the average mean temperature was 2 plus degrees higher.

It took 27.75 total mean days at an average mean temperature of 62.62° F. for *L. oblineatus* to pass through the five stadia at Blackduck, 1942.

DEVELOPMENT OF MIRIDAE FROM EGG TO ADULT

The complete life cycles for the three species of Miridae are summarized in table 12. *A. lineolatus* completed the life stages in 33.50 days at St. Paul, 1941, at a mean temperature of 78.20° F. for the period while it required 46.02 days at Blackduck in 1942 when the mean temperature was 63.20° F.

A. rapidus passed through these stages in 30.90 days at St. Paul in 1941 when the average mean temperature was 80.39° F.

L. oblineatus required 42.25 days at a mean temperature of 63.00° F. to change from newly laid eggs to adults at Blackduck during the summer of 1942.

Results of the cage studies corresponded closely to findings in the field where examinations and sweepings were made at different times to determine the presence and abundance of the developmental stages of the three species. Approximately the same time was necessary for development of eggs and nymphs under field conditions as was required in cages.

The lower temperatures retarded development and the moderately high temperatures gave impetus to it.

The effects of temperature on the length of the life stages may be seen more clearly in table 13, which gives day-degrees for the incubation period and nymphal stadia of the three species.

The lower mean temperatures at Blackduck, 1942, resulted in a longer incubation period for *A. lineolatus* than was required at St. Paul, 1941, when mean temperatures were considerably higher; this likewise applies to the various nymphal stadia, with one exception.

When time and temperature are considered together, the requirements for development seem to be more nearly alike for a given stage or instar within the species. Low mean temperatures apparently retard development to the extent that the day-degrees are increased over those of higher mean temperatures.

Mirid Infestation and Experimental Control Methods

The *Adelphocoris lineolatus* specimens in the University of Minnesota collection prior to 1939 were taken by the various collectors in miscellaneous sweeps and, therefore, do not necessarily represent the actual distribution of this species in Minnesota. It is logical, however, to assume, from the fact that the specimens were collected in increasing numbers and from additional counties beginning in 1933, that the *A. lineolatus* popula-

Table 12. Summary of Life Cycle Data for *A. lineolatus*, *A. rapidus*, and *L. oblineatus*, St. Paul and Blackduck, Minnesota, 1941-1942
(Time expressed in mean days)

Developmental dates	*A. lineolatus* St. Paul—1941 6/25-8/3		*A. lineolatus* St. Paul—1941 7/6-8/3		*A. lineolatus* Blackduck—1942 7/25-9/14		*A. rapidus* St. Paul—1941 7/29-8/1		*L. oblineatus* Blackduck—1942 7/27-9/7	
	Number	Development (days)	Number	Development (days)	Number	Development (days)	Number	Development (days)	Number	Development (days)
Incubation (eggs)	66	15.03	78	15.44	82	17.72	72	15.50	34	14.50
First instar (nymphs)	17	4.94	40	3.08	42	5.31	13	3.85	8	5.75
Second instar (nymphs)	17	2.88	30	2.33	36	3.80	12	2.42	6	4.17
Third instar (nymphs)	13	2.54	26	2.50	30	5.10	10	1.80	6	3.83
Fourth instar (nymphs)	9	3.22	12	3.00	23	5.09	5	3.00	5	5.00
Fifth instar (nymphs)	9	4.89	......	....	19	9.00	3	4.33	5	9.00
Length life cycle (days)		33.50		....		46.02		30.90		42.25
Mean temperature—°F.										
Maximum		89.61				72.12		91.84		72.12
Minimum		66.79				54.29		68.95		53.88
Average		78.20				63.20		80.39		63.00
Precipitation (inches)		.065				.997		.035		.132

Table 13. Mean Day-degrees Required for the Development of Life Stages of *A. lineolatus*, *A. rapidus*, and *L. oblineatus*, St. Paul and Blackduck, Minnesota, 1941-1942

	A. lineolatus	*A. lineolatus*	*A. lineolatus*	*A. rapidus*	*L. oblineatus*	*L. oblineatus*
	St. Paul—1941	St. Paul—1941	Blackduck—1942	St. Paul—1941	St. Paul—1941	Blackduck—1942
Developmental stage	Day-degrees	Day-degrees	Day-degrees	Day-degrees	Day-degrees	Day-degrees
Egg	1,094	1,137	1,161	1,136	828	941
First instar	350	262	343	297	....	360
Second instar	223	196	235	196	....	260
Third instar	204	208	328	150	....	241
Fourth instar	269	247	307	254	....	318
Fifth instar	411	....	561	358	....	557
Egg to adult	2,551	....	2,936	2,391	....	2,677

tion was increasing and spreading. *A. lineolatus* was found to be abundant in alfalfa fields in 1939.

During 1940, 1941, and 1942, the writer attempted to determine as nearly as possible the population intensities of *A. lineolatus, A. rapidus,* and *Lygus* spp. in representative alfalfa fields at St. Paul and in northern Minnesota.

Two methods of taking population counts were used. Both methods are accepted generally. Under the method used in 1940 and 1941, the writer took 50 consecutive sweeps with a 12-inch insect net as he walked rapidly through the alfalfa. All insects collected were killed in a large cyanide jar; then they were removed to another container and counted later. A sufficient number of samplings was made in each field to obtain a representative count. In 1942, the sweeps with a 12-inch insect net were made in groups of 10 from five different locations in a field. When this number of sweeps was made at one time, the mirids were counted as they were released gradually from the net and drawn into an aspirator. Two or three consecutive insect counts of 50 were often taken in a single alfalfa field. The counts were recorded in a field book.

The alfalfa fields checked for mirid infestation in 1940 and 1941 were located at St. Paul and in northern Minnesota. None had been treated for mirid control.

In 1942, only northern Minnesota alfalfa fields were checked. These were both untreated and treated fields. Table 14 makes available information pertaining to the acreage under cultural control and the untreated acreage serving as a check against the treated acreage.

Arrangements were made during the fall of 1941 and the spring of 1942 for the writer to observe 863.25 acres of alfalfa that were to be kept for seed. Of this amount 579.75 acres were to be treated for bug control and 283.50 acres were to remain untreated. The acres lost to this study during the season totaled 234. Sixty-six and one-half acres of alfalfa were winterkilled; 112 acres were cut for hay; 17.5 acres were removed because of aphid infestation; and 38 acres were not included due to miscellaneous reasons of the growers. There were 629.25 acres kept for seed, of which 451.75 were treated and 177.50 acres were untreated.

The mirid population was similar in all varieties of alfalfa. Grimm alfalfa is the most common variety in Minnesota, but some Laydak and Cossack are grown and are included in this study.

Table 14. Acres of Alfalfa under Observation in Northern Minnesota (1942)

County	Coopera-tors	Approximate acreage alfalfa grown (hay and seed) on farms observed	Acres for seed beginning of season	Acres elimi-nated before end of season	Classification of alfalfa seed fields and acreage at end of season					
					Thoroughly burnt-over	Partially burnt-over	Culti-vated	Burnt-over and cultivated	Not treated	Total acres end of season
Beltrami	18	791.5	422.25	84.0	55.0	100.0	111.75	37.0	34.5	338.25
Clearwater	2	90.0	20.00	12.0	5.0	....	....	3.0	....	8.00
Itasca	3	96.0	21.00	21.0	....	....	....	....	....	....
Koochiching	2	45.0	12.00	....	....	....	....	7.0	5.0	12.00
Lake of the Woods	15	613.0	305.00	76.0	69.0	16.0	10.00	16.0	118.0	229.00
Roseau	3	165.0	63.00	23.0	12.0	8.0	....	....	20.0	40.00
St. Louis	1	40.0	20.00	18.0	2.0	....	....	....	....	2.00
	44	1,840.5	863.25	234.0	143.0	124.0	121.75	63.0	177.5	629.25

MIRID INFESTATION OF UNTREATED ALFALFA

Population counts to ascertain the intensities of *A. lineolatus, A. rapidus,* and *Lygus* spp. in alfalfa not treated for bug control were made in new and in old seeding.

The mean population of Adelphocoris bugs in new seeding was generally lower than in old seeding. Perhaps this was due to insufficient alfalfa vegetation in new seeding for overwintering *A. lineolatus* and *A. rapidus* eggs and, also, to a low adult population after the nurse crop had been removed from the field the previous year.

There were as many *Lygus* spp. in new seeding as in old seeding, or there were more. Since Lygus bugs overwinter as adults, they may remain under various types of vegetation or debris and do not necessarily depend on alfalfa for protection. Also, they may fly to the alfalfa from various other overwintering habitats in the spring and early summer.

When the populations of the Adelphocoris bugs and Lygus bugs were compared, there were more Adelphocoris bugs in old seeding than there were Lygus bugs; Lygus bugs were more numerous in new seeding.

The average number of Miridae per 50 sweeps was less on first- and second-year alfalfa on new ground that was isolated from other alfalfa fields and which had not been treated for insect control than the average number on any other untreated alfalfa fields. It was reported that alfalfa produced comparatively good seed on such fields the first year and then the amount decreased to a possible seed failure within two to four years. Thus it is only logical to suppose that the decrease in yield is correlated with the increase in bug population.

Sixty-three population counts were taken in various types of untreated alfalfa fields, intended for hay or seed, during 1940, 1941, and 1942. The St. Paul counts were made at University Farm; the northern Minnesota counts were made in the counties of Beltrami, Lake of the Woods, Roseau, Koochiching, Itasca, St. Louis, and Clearwater. The data are summarized in table 15.

Weather conditions were less favorable for Miridae in 1942 than in 1940 and 1941. Low mean daily temperatures and frequent rains retarded their development. This is borne out by the 1942 population counts for all Miridae. The average number of insects per 50 sweeps is lower in each instance. *A. lineolatus* was most abundant in late August and early September which was at least one month later than in 1941.

Table 15. Populations of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. in All Untreated Fields Studied at St. Paul, 1940-1941, and in Northern Minnesota, 1941-1942

Species	Population counts	Adults	Nymphs	Total	Average bugs per 50 sweeps	Per cent of all Miridae for period shown
St. Paul—1940						
8/7-9/17	4					
A. lineolatus		196	8	204	51.00	22.17
A. rapidus		22	8	30	7.50	3.26
Lygus spp.		654	32	686	171.50	74.57
		872	48	920	230.00*	
St. Paul—1941						
6/17-7/27	5					
A. lineolatus		325	182	507	101.40	28.97
A. rapidus		37	13	50	10.00	2.86
Lygus spp.		689	504	1,193	238.60	68.17
		1,051	699	1,750	350.00*	
Northern Minnesota—1941						
8/4-8/21	9					
A. lineolatus		1,050	1,481	2,531	281.22	66.89
A. rapidus		16	15	31	3.44	0.82
Lygus spp.		594	628	1,222	135.77	32.29
		1,660	2,124	3,784	420.44*	
Northern Minnesota—1942						
6/18-9/19	45					
A. lineolatus		766	1,477	2,243	49.84	34.14
A. rapidus		22	27	49	1.08	0.75
Lygus spp.		2,404	1,874	4,278	95.06	65.11
		3,192	3,378	6,570	146.00*	

* Average is total bugs of all three species divided by population counts.

At St. Paul (1940 and 1941) and in northern Minnesota (1942), the number of *Lygus* spp. per 50 sweeps exceeded the number of *A. lineolatus*. In northern Minnesota (1941), *A. lineolatus* was more than double the number of *Lygus* spp. This was based on nine population counts made between August 4 and August 21. Inasmuch as there seems to be an overlapping of the generations of *A. lineolatus* about this period, the high number of *A. lineolatus* may be accounted for by this reasoning. The average of *A. lineolatus* per 50 sweeps for the August 4-August 21 period was 281.22. The greatest number taken at a single count was 1,075 in Roseau County. This species usually ranged from 100 to 200 per 50 sweeps.

A. rapidus represented a very small percentage (0.75 per cent) of the Miridae in the untreated fields in 1942. This species was more abundant at St. Paul than it was in northern Minnesota, but its highest average there was only 3.26 per cent (1940).

The writer had arranged to check 283.5 acres of untreated alfalfa that were to be saved for seed in 1942. These were to serve as a control against the variously treated fields. However, 20 acres of this alfalfa were winterkilled, 48 acres were cut for hay, and 38 acres were eliminated for miscellaneous reasons. The total untreated acreage under observation during the summer of 1942 was, therefore, 177.5 acres.

The population counts on these untreated acres are presented in table 16. The Adelphocoris bugs were most numerous in the fields in June and early September; Lygus bugs were most numerous in July and early September. From June 18 to September 19, *A. lineolatus* averaged 49.84 bugs per 50 sweeps; *A. rapidus,* 1.08; and *Lygus* spp., 95.06. All Miridae for the summer averaged 146 per 50 sweeps.

Lygus spp. comprised 65.11 per cent of all the Miridae collected in the untreated fields (1942). The mirid population in untreated fields in 1942 was much lower than in 1940 and 1941 (table 15), but it was higher than on any of the treated fields as shall be shown in following paragraphs.

Table 16. Populations of *A. lineolatus, A. rapidus,* and *Lygus* spp. by Month in Untreated Alfalfa Fields, Northern Minnesota, 1942

Period (1942)	Population counts	Adults	Nymphs	Total	Bugs per 50 sweeps (mean)	Per cent of all Miridae for period shown
Adelphocoris lineolatus (Goeze)						
6/18-6/25	14	1	1,082	1,083	77.35	70.42
7/3-7/31	18	337	294	631	35.05	17.47
8/1-8/4	9	130	58	188	20.88	51.09
9/9-9/19	4	298	43	341	85.25	32.41
6/18-9/19	45	766	1,477	2,243	49.84*	34.14
Adelphocoris rapidus (Say)						
6/18-6/25	14	None	19	19	1.35	1.23
7/3-7/31	18	8	3	11	.61	.30
8/1-8/4	9	13	5	18	2.00	4.89
9/9-9/19	4	1	None	1	.25	.10
6/18-9/19	45	22	27	49	1.08*	.75
Lygus spp.						
6/18-6/25	14	41	395	436	31.14	28.35
7/3-7/31	18	1,706	1,264	2,970	165.00	82.23
8/1-8/4	9	63	99	162	18.00	44.02
9/9-9/19	4	594	116	710	177.50	67.49
6/18-9/19	45	2,404	1,874	4,278	95.06*	65.11
All species						
6/18-9/19					146.00*	

* Average is total bugs divided by total population counts.

MIRID CONTROL STUDIES

The control of *A. lineolatus* and *A. rapidus* can best be accomplished by destroying the overwintering eggs. Such a control would also destroy many of the overwintering adults of *Lygus* spp. Any treatment to accomplish this must be made early in the spring, for the eggs of the Adelphocoris bugs have been noted to hatch by May 11 and Lygus bugs have been collected in the field in April.

In order to have a control program under way as soon as spring weather of 1942 would permit, the writer interviewed some 50 alfalfa growers in the counties of Beltrami, Clearwater, Lake of the Woods, Roseau, Koochiching, Itasca, and St. Louis during the fall of 1941. These interviews brought forth a variety of reasons why the alfalfa-seed crops had been virtual failures from year to year since the decrease in production began about 10 years ago. In no instance were insects, other than grasshoppers, thrips, and bees, taken into consideration. It was more than interesting, therefore, to note the growers' reactions to the mirid population in the alfalfa fields. *A. lineolatus, A. rapidus,* and *Lygus* spp. were particularly abundant in the Minnesota fields in 1941 and the number collected in an insect net in 50 sweeps averaged 398.85 for St. Paul and the northern part of the state. This was a convincing demonstration to the most skeptical that a control to rid the alfalfa of these pests would be beneficial. Without the wholehearted and conscientious cooperation which these growers gave, the control experiments in 1942 would have been impossible.

The plan was to try, by cultural or chemical control methods, to reduce the number of Miridae on alfalfa under natural growing conditions. The fields represented different types of growth, different soils, different degrees of infestation, and different locations.

Two forms of cultural control seemed best adapted for this purpose. Burning-over of alfalfa straw and stubbles should destroy the overwintering eggs of Adelphocoris bugs and many of the overwintering adults of Lygus bugs; cultivation of fields should destroy overwintering stages by covering them with soil. It was thought worth-while, also, to try a combination of these two methods on certain fields.

When the experiments were completed, the cultural control applied suggested classifications of: (1) thoroughly burnt-over fields; (2) partially burnt-over fields; (3) cultivated fields; and (4) burnt-over and cultivated fields.

Sulphur dust and pyrocide were used separately on experimental plots to see how the insects would react to chemical control. The results of these experiments will be considered after cultural control is discussed.

Thoroughly Burnt-over Alfalfa Fields

Alfalfa stems and stubbles should be burnt close to the ground in order that *A. lineolatus* and *A. rapidus* overwintering eggs, which are laid in the alfalfa stems and often near the soil, may be destroyed most effectively. Thorough burning of this type will also eliminate many of the overwintering adults of *Lygus* spp. which remain under leaves, grass, and debris at the surface of the ground. The entire field should be burnt-over with no unburnt spots left to serve as sources of infestation. Nearby volunteer alfalfa plants should be similarly destroyed. They should be cut close to the ground and removed to a safe place for burning to prevent unnecessary spread of fire. Likewise, alfalfa-straw stacks, remaining from the previous year's seed harvest, should be burnt as they may harbor *A. lineolatus* and *A. rapidus* eggs.

Fields should be burnt in the early spring just as soon as they are dried off sufficiently. This early burning is not only important if the insects are to be destroyed, but also because there is less danger of causing forest fire if the burning is done before the forest floor is dry. When burning is practiced, it should be done before the new plant growth develops very far. The addition to the soil of the charred remains of plant tissues often improves alfalfa growth.

Late spring and early summer burning are not advisable, yet one experiment is worthy of note. One alfalfa grower in Beltrami County cut 7 acres of an approximately 30-acre field of Laydak alfalfa on June 20. The growth had been heavy. The hay was left on the field in swaths until July 4 when it was burnt. For two or three weeks afterward there was little indication of plant life in the charred remains. Development then came about rapidly and in September the alfalfa appeared in excellent condition and yielded two tons of hay per acre, which was as good as, or better than, the remainder of the large field.

Some late fall burning was tried in 1941, but it was unsuccessful for two reasons. First, in the fall there were considerable quantities of green alfalfa and weeds on the fields that would not burn readily; and, secondly, frequent rains kept the alfalfa straw wet. Fall burning is objectionable anyway as there is too much danger of winterkill when the vegetative cover is removed, especially when not enough snow falls to provide protection. Some acreage was lost in 1942 due to winterkill on fields that had been cut for hay in the late fall of 1941. There was less snow than usual in northern Minnesota during the winter of 1941-1942 and the alfalfa which had been cut close to the ground had little or no protection.

Fields which are covered with heavy growth that is evenly distributed are quite easy to burn-over thoroughly. When an entire crop of old alfalfa straw was burnt during favorable dry spring weather, a terrific heat was produced by a 6- to 15-foot blaze. A 10-acre field may be burnt-over in half an hour or so. If there is insufficient growth to produce a hot fire, a 4- or 5-inch layer of straw may be scattered evenly over the field and burnt.

Moroshkina and Akimova *(11)* reported that *A. lineolatus* eggs were successfully destroyed in Russia by burning 4 inches of straw over the alfalfa stubbles in late March. They stated that the seed yield on these well-burnt fields was good.

When a field of standing alfalfa is burnt well, the field is left clean of weeds, leaves, and other plant debris and the alfalfa stems are charred close to the surface of the ground.

One objection to burning is, of course, the possibility of the fire getting out of control and wastefully destroying valuable natural resources and land improvements. The need for precaution can never be overemphasized. The growers participating in this project were very cautious and, though 370 acres were fired, the blaze did not get out of control in a single instance. Occasionally, it burnt along the fence rows or edges of the field, but it did not spread beyond. As a precautionary measure, one grower borrowed fire-fighting equipment from a neighboring ranger station. This was highly commendable. A burning permit should always be obtained from a fire warden or other authorized agent before any burning is done.

Only old-seeding alfalfa was treated by burning. The growers thought that the new-seeding plants, those less than one-year old, would be seriously damaged by the heat. Burning of the old seeding did not cause any obvious injury to the alfalfa crowns or roots.

Some burning-over of alfalfa stubbles by means of an oil burner or flame thrower was planned for the spring of 1943.

Of the 330 acres burnt-over, 143 were thoroughly burnt-over.

Population counts were made in these fields at various intervals from June 16 to September 12 (1942). The data are summarized by month in table 17. The population in these well-burnt fields was much lower than in other fields. Many of these fields had been examined in 1941 and had a high bug count per 50 sweeps.

During June when 18 population counts were made, the mean number of *A. lineolatus* per 50 sweeps was 2, with a range from zero to 14. It was 97.41 per cent less than for this species in untreated alfalfa. The mean population increased to slightly more than 8 per 50 sweeps in July and August. Based on population counts in early September, the mean number was 51 per 50 sweeps. At that time the second-generation nymphs and adults were present in larger numbers in the fields due to reproduction and migration. The greatest number taken of *A. lineolatus* per 50 sweeps was 80 on September 9 (1942). *A. lineolatus* comprised 24.31 per cent of the mirid population for the summer with a range from 21.43 per cent in August to 27.69 per cent in June.

A. rapidus appeared in diminutive numbers all summer. It never averaged more than 1 per 50 sweeps and comprised only

Table 17. Populations of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. by Month in Thoroughly Burnt-over Alfalfa Fields, Northern Minnesota, 1942

Period (1942)	Population counts	Adults	Nymphs	Total	Bugs per 50 sweeps (mean)	Per cent of all Miridae for period shown
Adelphocoris lineolatus (Goeze)						
6/16-6/26	18	1	35	36	2.00	27.69
7/8-7/31	17	102	38	140	8.23	25.23
8/1-8/28	14	90	27	117	8.35	21.43
9/9-9/12	2	76	26	102	51.00	25.89
6/16-9/12	51	269	126	395	7.74*	24.31
Adelphocoris rapidus (Say)						
6/16-6/26	18	0	2	2	0.11	1.54
7/8-7/31	17	6	3	9	0.52	1.62
8/1-8/28	14	9	5	14	1.00	2.56
9/9-9/12	2	0	0	0	0.00	0.00
6/16-9/12	51	15	10	25	0.49*	1.54
Lygus spp.						
6/16-6/26	18	29	63	92	5.11	70.77
7/8-7/31	17	201	205	406	23.88	73.15
8/1-8/28	14	167	248	415	29.64	76.01
9/9-9/12	2	207	85	292	146.00	74.11
6/16-9/12	51	604	601	1,205	23.62*	74.15
All species						
6/16-9/12					31.86*	

* Average is total bugs divided by total population counts.

1.54 per cent of the total mirid population in the thoroughly burnt-over fields that summer.

The Lygus bugs were the most common of all the Miridae in the field. There were not many Lygus bugs per 50 sweeps in the field in June (5.11), but the number increased to 23.88 in July and to 29.64 in August. Based on the two September counts, there were 146 per 50 sweeps. Of all the mirids in thoroughly burnt-over fields in 1942, *Lygus* spp. averaged 74.15 per cent.

Partially Burnt-over Alfalfa Fields

Burning was not always thorough. Sometimes entire fields were only lightly burnt-over or some areas were not touched by fire. These fields have been considered as only partially burnt-over. This condition was the result of poor burning (1) when combined alfalfa straw was spread unevenly over the alfalfa stubble; (2) when straw was scattered lightly over the fields; (3) when stands of alfalfa that were left over winter (usually second-cutting) were too light for a good spring burn; (4) when thin areas (caused by winterkill or poor soil) in otherwise heavy stands were not specially treated; and (5) when burning was undertaken before the fields were sufficiently dry.

Where the entire fields were only lightly burnt, there was not enough fire to destroy all overwintering stages of mirids. In other fields, the untreated areas harbored a sufficient number of bugs to infest the whole fields during the summer.

Population counts were taken in 124 acres of partially burnt-over alfalfa. When the fields were examined in early June, 1942, there were 196 acres of burnt-over alfalfa classed as partially burnt-over; by late June, 72 acres were eliminated by being winterkilled, cut for hay, or plowed under because a heavy infestation of aphids was mistaken for *A. lineolatus* nymphs.

Thirty-five population counts were made in partially burnt-over alfalfa from June 16 to September 4, 1942, inclusive (table 18). The mean number of *A. lineolatus* per 50 sweeps was 36.25 in contrast to 7.74 per 50 sweeps in thoroughly burnt-over fields for the summer. The number increased from 15.11 per 50 sweeps in June to 56.00 per 50 sweeps in September. *A. rapidus* represented less than 1 per cent of the summer's mirid catch.

Lygus spp. were less numerous in June (11.55 per 50 sweeps) than *A. lineolatus*, but were more abundant in July and August. The *Lygus* spp. average for the summer was 67.97 bugs per 50 sweeps in partially burnt-over alfalfa. They made up 64.61 per

Table 18. Populations of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. by Month in Partially Burnt-over Alfalfa Fields, Northern Minnesota, 1942

Period (1942)	Population counts	Adults	Nymphs	Total	Bugs per 50 sweeps (mean)	Per cent of all Miridae for period shown
Adelphocoris lineolatus (Goeze)						
6/16-6/26	9	0	136	136	15.11	56.43
7/8-7/30	21	554	403	957	45.57	31.69
8/1-8/28	4	77	43	120	30.00	35.50
9/4	1	30	26	56	56.00	67.47
6/16-9/4	35	661	608	1,269	36.25*	34.47
Adelphocoris rapidus (Say)						
6/16-6/26	9	0	1	1	0.11	0.42
7/8-7/30	21	7	0	7	0.33	0.23
8/1-8/28	4	25	1	26	6.50	7.69
9/4	1	0	0	0	0.00	0.00
6/16-9/4	35	32	2	34	0.97*	0.92
Lygus spp.						
6/16-6/26	9	27	77	104	11.55	43.15
7/8-7/30	21	1,100	956	2,056	97.90	68.08
8/1-8/28	4	77	115	192	48.00	56.81
9/4	1	12	15	27	27.00	32.53
6/16-9/4	35	1,216	1,163	2,379	67.97*	64.61
All species						
6/16-9/4					105.2*	

* Average is total bugs divided by total population counts.

cent of all the Miridae taken in the partially burnt-over fields included in this study.

A. lineolatus, A. rapidus, and *Lygus* spp. combined had a mean population of 105.2 per 50 sweeps in partially burnt-over alfalfa for the entire period and only 31.86 per 50 sweeps in thoroughly burnt-over alfalfa.

Cultivated Alfalfa Fields

Cultivation of alfalfa fields, following removal of the crop for hay or seed, is a common practice in northern Minnesota. It is done for the purpose of removing weeds, quackgrass (*Agropyron repens* [L.] Beauv.) in particular, during early spring, late summer, or fall. The soil is often thoroughly stirred or "blackened" to a depth of 2 or 3 inches. There is little apparent plant life after a field has been twice cultivated, the cultivator being run the length of the field the first time and the width the second.

Cultivation is not recommended generally in the United States since it may injure the alfalfa crowns and thus predispose the plants to bacterial wilt or other diseases, which are prevalent in some areas, and since the plants may also suffer from mechanical injury. The damage, if any, to the fields under observation in 1942 was insignificant.

New seeding is seldom cultivated as the young and not too well-established plants may be pulled from the ground. One field of new seeding examined the summer of 1942 had been heavily cultivated and smooth-dragged that spring and there was no apparent injury to the plants; however, it probably would not be wise to cultivate new seeding.

Population counts were taken in fields that were cultivated in the spring of 1942 to try to determine whether an appreciable number of *A. lineolatus* and *A. rapidus* eggs would be destroyed when covered over with soil as a result of cultivation.

The degree of thoroughness with which the fields were cultivated was not uniform and some cooperators did not cultivate as early in the spring as others did. Cultivation seemed to retard the alfalfa growth and especially so when it was done in late April or in May.

It is difficult, because of these inconsistencies, to draw any definite conclusions from the data at hand, but it is very likely that cultivation is an ineffective control. It is possible that thorough cultivation of alfalfa stubbles in late summer would eliminate many stems in which overwintering eggs of *A. lineolatus* and *A. rapidus* are ordinarily laid; however, winterkill sometimes results from fall cultivation, especially when the snow cover is light.

From general observations, it can be said that cultivation should be thorough to accomplish even a minimum of good. Cultivation may be more effective in preventing a rapid increase in population than it would be in reducing a heavy infestation.

A. lineolatus comprised 33.97 per cent of the total mirid population in cultivated fields in which population counts were taken (1942); *A. rapidus,* 4.31 per cent; and *Lygus* spp., 61.72 per cent.

The data are shown in table 19.

Burnt-over and Cultivated Fields

Sixty-three acres of alfalfa were burnt-over and then cultivated for the purpose of this control study. Thirty-three of this number had all of the 1941 alfalfa straw standing on the fields and this acreage burnt-over thoroughly. Five acres were covered with a thin layer of oats straw, scattered by means of a manure spreader. The fire completely covered this field, but was too light to destroy all the stubbles. The remaining 25 acres had

Table 19. Populations of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. by month in Cultivated Alfalfa Fields, Northern Minnesota, 1942

Period (1942)	Population counts	Adults	Nymphs	Total	Bugs per 50 sweeps (mean)	Per cent of all Miridae for period shown
Adelphocoris lineolatus (Goeze)						
6/17-6/19	3	0	151	151	50.33	44.94
7/6-7/31	8	163	41	204	25.50	23.89
8/3	2	99	11	110	55.00	61.45
6/17-8/3	13	262	203	465	35.76*	33.97
Adelphocoris rapidus (Say)						
6/17-6/19	3	0	1	1	0.33	0.30
7/6-7/31	8	5	0	5	0.62	0.58
8/3	2	41	12	53	26.50	29.61
6/17-8/3	13	46	13	59	4.53*	4.31
Lygus spp.						
6/17-6/19	3	28	156	184	61.33	54.76
7/6-7/31	8	398	247	645	80.62	75.53
8/3	2	3	13	16	8.00	8.94
6/17-8/3	13	429	416	845	65.00*	61.72
All species						
6/17-8/3					105.3*	

* Average is total bugs divided by total population counts.

scattered, combined alfalfa straw or alfalfa in windrows burnt over them during early spring. Bugs were less numerous on the alfalfa which had been thoroughly burnt-over. They averaged 55.66 per 50 sweeps (6 counts) in the thoroughly burnt-over and cultivated alfalfa as against 96.22 per 50 sweeps (15 counts) in partially burnt-over and cultivated alfalfa.

The population counts on all burnt-over and cultivated alfalfa fields are summarized in table 20. Twenty population counts were taken from June 17 to September 8. The average number of *A. lineolatus* per 50 sweeps was 32.8; of *A. rapidus,* 0.45; and of *Lygus* spp., 50.05. The average of all Miridae for the summer was 83.3 which would indicate that a combination of burning and cultivating is more effective than cultivating alone.

The mirid population for the summer consisted of 39.38 per cent *A. lineolatus;* 0.54 per cent *A. rapidus;* and 60.08 per cent *Lygus* spp.

Comparative Study

Data on population intensity, as detailed in tables 16, 17, 18, 19, and 20, are summarized in tabular form. Table 21 shows, in group I, the total number of *Adelphocoris lineolatus, Adelphocoris*

Table 20. Populations of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. by Month in Burnt-over and Cultivated Alfalfa Fields, Northern Minnesota, 1942

Period (1942)	Population counts	Adults	Nymphs	Total	Bugs per 50 sweeps (mean)	Per cent of all Miridae for period shown
Adelphocoris lineolatus (Goeze)						
6/17-6/24	4	0	78	78	19.50	60.46
7/8-7/31	10	159	63	222	22.20	38.08
8/3-8/28	3	27	17	44	14.66	10.38
9/8	3	231	81	312	104.00	58.87
6/17-9/8	20	417	239	656	32.80*	39.38
Adelphocoris rapidus (Say)						
6/17-6/24	4	0	1	1	0.25	0.78
7/8-7/31	10	5	2	7	0.70	1.20
8/3-8/28	3	0	1	1	0.33	0.23
9/8	3	0	0	0	0.00	0.00
6/17-9/8	20	5	4	9	0.45*	0.54
Lygus spp.						
6/17-6/24	4	3	47	50	12.50	38.76
7/8-7/31	10	200	154	354	35.40	60.72
8/3-8/28	3	164	215	379	126.33	89.39
9/8	3	145	73	218	72.66	41.13
6/17-9/8	20	512	489	1,001	50.05*	60.08
All species						
6/17-9/8					83.3*	

* Average is total bugs divided by total population counts.

rapidus, and *Lygus* spp. and the number of population counts; in group II, the mean per 50 sweeps; and, in group III, the per cent of each in treated and untreated fields under observation in northern Minnesota (1942).

The figures thus presented permit an analysis of the mirid infestation of *A. lineolatus*, of *A. rapidus*, and of *Lygus* spp. in their relation to untreated fields and to fields that were thoroughly burnt-over, partially burnt-over, cultivated, and burnt-over and cultivated. The figures also furnish a basis for comparative analyses of *A. lineolatus*, *A. rapidus*, and *Lygus* spp. in their relation to the untreated and the treated fields.

By examining the figures in group II, Miridae per 50 sweeps (mean), the results of the various methods of treatment on the mirid populations will be noted.

In untreated alfalfa, the average of *A. lineolatus* per 50 sweeps was 49.84 bugs. The average in thoroughly burnt-over fields was only 15.52 per cent of this number, or 7.74 bugs. In other treated fields, the averages were 36.25 (72.73 per cent) for

Table 21. Summary of Population Intensities for *A. lineolatus*, *A. rapidus*, and *Lygus* spp. in Treated and Untreated Alfalfa Fields, Northern Minnesota, 1942

Method of treatment	Population counts	Group I Total Miridae			Group II Mirids per 50 sweeps (mean)			Group III Per cent of total mirid population each kind of field		
		A. lineolatus	*A. rapidus*	*Lygus* spp.	*A. lineolatus*	*A. rapidus*	*Lygus* spp.	*A. lineolatus*	*A. rapidus*	*Lygus* spp.
Untreated	45	2,243	49	4,278	49.84	1.08	95.06	34.14	0.75	65.11
Thoroughly burnt-over	51	395	25	1,205	7.74	0.49	23.62	24.31	1.54	74.15
Partially burnt-over	35	1,269	34	2,379	36.25	0.97	67.97	34.47	0.92	64.61
Cultivated	13	465	59	845	35.76	4.53	65.00	33.97	4.31	61.72
Burnt-over and cultivated	20	656	9	1,001	32.80	0.45	50.05	39.38	0.54	60.08

partially burnt-over fields, 35.76 (71.74 per cent) for cultivated fields, and 32.8 (65.81 per cent) for burnt-over and cultivated fields. These averages are from 50.29 to 57.21 per cent higher than the average in the thoroughly burnt-over fields. The order of the treated fields ranging from the most effectively treated to the least effectively treated for *A. lineolatus* would be, therefore, thoroughly burnt-over—average 7.74 bugs per 50 sweeps; burnt-over and cultivated—average 32.8; cultivated—average 35.76; and partially burnt-over—average 36.25. It is apparent that, in these studies, a thorough burn reduced the *A. lineolatus* population noticeably. Had the burnt-over and cultivated fields been more uniformly treated, it is very probable that the *A. lineolatus* population would have been lower. There is little difference between the results obtained in cultivated fields and in partially burnt-over fields. The *A. lineolatus* population was reduced approximately 25 per cent by each of these methods of treatment.

A. rapidus was present in limited numbers in the various fields. An abnormally high number was taken in one cultivated field where *A. rapidus* made up 29.61 per cent of the total mirid population for the period. This made an average per 50 sweeps for cultivated fields of 4.53 bugs. The average in untreated fields was only 1.08; thoroughly burnt-over, 0.49; partially burnt-over, 0.97; and burnt-over and cultivated, 0.45.

Lygus spp. in untreated fields averaged 95.06 per 50 sweeps. The order of the treated fields ranging from the most effectively treated to the least effectively treated with regard to *Lygus* spp. is the same as for *A. lineolatus*. The average in thoroughly burnt-over fields was 23.62; in burnt-over and cultivated, 50.05; in cultivated, 65.00; and in partially burnt-over, 67.97.

Group III indicates what per cent of the total Miridae was represented by each species in the various fields, both treated and untreated. A graph based on these percentages has been prepared (figure 14) to show the approximate ratio between *A. lineolatus* and *Lygus* spp. *A. rapidus* is present in such small numbers that it is not included. This graph provides a comparative picture of the results of the four methods of treatment on the *A. lineolatus* population and on the *Lygus* spp. population.

Lygus spp. in untreated fields had almost twice the intensity that *A. lineolatus* had. The ratio in partially burnt-over fields remained about the same, which would indicate that overwintering forms of both *A. lineolatus* and *Lygus* spp. survived the treatment at a ratio of 1 to 2, respectively.

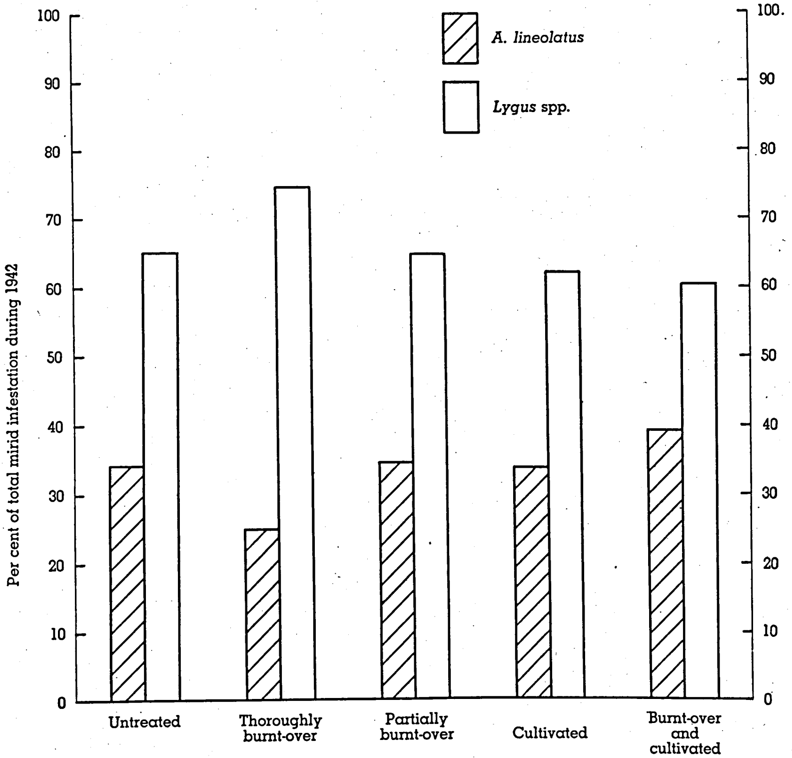

FIG. 14. Comparative study of population intensities of *A. lineolatus* and *Lygus* spp. in treated and untreated alfalfa fields of northern Minnesota, 1942

The next nearest ratio to that between *A. lineolatus* and *Lygus* spp. in untreated fields was in cultivated fields where there were fewer of each in the fields, but the reduction in the *Lygus* spp. population was 3.37 per cent greater than in the *A. lineolatus* population.

In burnt-over and cultivated fields, the *A. lineolatus* population represented a larger per cent of the two species than it did in untreated fields; *Lygus* spp. was less than in untreated fields. There were approximately two *A. lineolatus* to every three *Lygus* spp. As previously explained, the burnt-over and cultivated fields were not treated uniformly. The figures may be interpreted as proving that thorough burns were not always achieved, hence the greater number of *A. lineolatus* in proportion to *Lygus* than in other treated fields.

The per cent of *A. lineolatus* in the thoroughly burnt-over fields was less than in any other fields, while that of *Lygus* spp.

was greater than in any other fields; the ratio was approximately 1 to 3. It is possible that many of the Lygus bugs were active enough at the time the fields were burnt to escape from the fields and thus avoid destruction. When the new growth appeared on the burnt-over fields, these insects may have come from other alfalfa fields and increased the population in this way. A few *A. lineolatus* nymphs migrated from nearby fields at an early date. Adults of this species undoubtedly began flying in from other fields during late June.

Chemical Control

In addition to the foregoing cultural control program for *A. lineolatus, A. rapidus,* and *Lygus* spp., limited chemical control experiments were tried in 1942. Some cage studies supplemented the open field experiments.

Eight one-half acre plots of new-seeding alfalfa on two well-separated farms in Beltrami County were staked off for this work. The study was begun in mid-June and was continued throughout the summer. At the time the dusting was done, the alfalfa was in the early bloom stage. *Adelphocoris* nymphs, and a very few *Adelphocoris* adults, and *Lygus* nymphs and adults were present in the fields.

Two insecticides, dusting sulphur and pyrethrum (dry pyrocide), were employed separately. The pyrethrum contained 10 per cent dry pyrocide with 4 per cent petroleum solution of pyrethrins as the active ingredients and 96 per cent talc as an inert diluent. The insecticides were used at rates of 20, 25, or 30 pounds per acre.

A hand duster was used to apply the insecticides. Dusting sulphur was tested on two plots; pyrethrum on three; and the remaining three plots were left untreated to serve as controls against the other five. The alfalfa was dusted at different times of the day, usually afternoons.

Unfavorable weather conditions interfered with this work. Showers occurred on 15 days of the 25-day period from June 15 to July 9. There were never more than two successive days without at least a trace of rain. Regardless of the rainfall and the relatively cool weather, the experiments were continued.

Insect counts were made in each of the alfalfa plots prior to the application of an insecticide and counts were also taken in the check plots. Within one to three hours after treatment, counts were again made to determine the immediate knockdown and/or killing power of the chemicals. A second application was made within four to six days after the first on all but one plot.

Cage studies were conducted simultaneously with the field studies. The cages were supported over alfalfa plants and 22 *A. lineolatus, A. rapidus,* and *Lygus* spp. were introduced into each cage. The enclosed area was dusted with the respective chemical and the insects' behavior was observed.

A summary of the data obtained in this investigation of the effects of sulphur and pyrethrum on Miridae is given in table 22.

Sulphur, dusted 25 or 30 pounds to the acre, brought about little, if any, mirid knockdown or kill. The insect population in the fields and in cages showed no obvious reaction to the sulphur approximately two hours after its application or a maximum of six days afterward. The second population count for plot I was much lower than the first; however, the mean daily temperature had dropped 8.5° Fahrenheit and the mirids usually remained near the base of the stems when the weather was cool. Control plot VIII, to which no insecticide had been applied, showed a corresponding drop in bug population on the same day.

Sulphur had no apparent repelling effect on the Miridae which were present in the usual numbers in the sulphur-treated alfalfa all summer.

Better results were obtained from pyrethrum than from sulphur. Data for plots III, IV, and V show these results. The knockdown and/or kill varied from 54.3 to 94.6 per cent of the original populations and averaged 79.8 per cent. All species of Miridae were affected in a similar manner. An hour or more after pyrethrum had been applied, numerous mirids and other insects were seen on the ground and on the basal portions of the alfalfa plants. Some mirids on the ground were dead or partially paralyzed with the legs outstretched; others were crawling about slowly. The populations in these pyrethrum-treated plots built up rapidly within three or four days. This leads to the conclusion that more knockdown than kill had been achieved. As pyrethrum apparently soon lost any repelling effect it may have had, there was undoubtedly some migratory influx of Miridae from adjacent and untreated alfalfa. However, it is probable that the Miridae would not migrate from one source of food to another in sufficient numbers to repopulate the fields to the extent they did. It is more reasonable to assume that many Miridae had been affected only temporarily by the pyrethrum and had recovered.

The results were more certain in cage studies with pyrethrum,

Table 22. Experimental Studies in the Chemical Control of *A. lineolatus*, *A. rapidus*, and *Lygus* spp., Blackduck, Minnesota, 1942

Plot	Date	Mean daily temp. ° F.*	Application	Chemical	Amount per acre	Miridae per 50 sweeps: Just before dusting	Miridae per 50 sweeps: 1-3 hours after dusting	Miridae per 50 sweeps: 4-6 days after dusting	Knock-down and kill	Miridae inactive in cages: Soon after dusting	Miridae inactive in cages: 2-3 days after dusting
					Pounds				Per cent	Per cent	
I	6/30	63.0	1st	Sulphur	25	256	Same	161	None	None	None
	7/6	54.5	2nd	Sulphur	30	161	Same	253	None	None	None
II	7/3	52.5	1st	Sulphur	30	329	Same	243	None	None	None
III	7/1	57.5	1st	Pyrocide	25	256	......	103	....	....	....
	7/7	63.5	2nd	Pyrocide	20	103	47	194	54.3	....	....
IV	7/3	52.5	1st	Pyrocide	30	335	20	292	94.0	95.4	90.9
	7/7	63.5	2nd	Pyrocide	30	292	24	170	91.7	60.0	40.0
V	7/3	52.5	1st	Pyrocide	30	300	16	172	94.6	....	....
	7/7	63.5	2nd	Pyrocide	20	172	61	116	64.5	....	....
VI	6/18	61.0	None	Control	......	256	......	184	....	....	....
	7/9	67.5	None	Control	......	438	......	....	....	....	....
VII	7/3	52.5	None	Control	......	335	......	506	....	....	....
	7/11	68.0	None	Control	......	445	......	....	....	....	....
VIII	7/7	63.5	None	Control	......	326	......	192	....	....	....

* Weather records from Forest Ranger's Station, Blackduck, Minnesota.

as would naturally be expected. In two cages, the knockdown averaged 77.7 per cent with a subsequent recovery of 12.3 per cent. There were two other cages, results of which are not shown in table 22, set up over alfalfa plants just for the purpose of testing mirid reaction to a heavy dusting of pyrethrum. These cages, containing 20 and 22 mirids, respectively, were carefully dusted with pyrethrum. *A. lineolatus, A. rapidus,* and *Lygus* spp. became restless immediately and moved rapidly, running and flying, about the cages. They stroked their antennae as though cleaning them. Activity was followed by partial paralysis and extension of the hind legs. Within ten minutes, several had fallen to the bottom of the cages and were moving with difficulty. Nearly all had fallen and were inactive 30 minutes following the pyrethrum treatment. In one cage, there was an 85 per cent knockdown; a 35.2 per cent recovery and a 55 per cent kill. In the second cage, the knockdown was 100 per cent; a 22.8 per cent recovery and a 77.2 per cent kill.

Mirid injury to chemically treated alfalfa and to the untreated alfalfa in plots serving as checks was equally severe. The seed crop was very unsatisfactory.

Perhaps results of the chemical control experiments would have been more conclusive had entire fields been treated and had the weather been more favorable. Perhaps, also, more than two treatments would be required.

Sorenson *(19, 20)* reported on extensive insecticide studies pertaining to the control of *Lygus elisus* Van D. and *Lygus hesperus* Knight, two mirid pests on alfalfa in Utah. Pyrethrum (dry pyrocide) with 0.2 per cent pyrethrins by weight, dusted 30 pounds per acre, gave the best results of 12 insecticides or combinations of insecticides tried. Although it was found that the number of Lygus bugs could be appreciably reduced when treated with pyrethrum dust, the benefit derived was considered insufficient to warrant the high cost involved in such treatment.

Alfalfa-Seed Crop from Treated and Untreated Fields Under Observation in Northern Minnesota, 1942

Investigations in 1942 of the alfalfa-seed conditions in northern Minnesota included a check for seed production on the treated and untreated fields under observation that year.

Table 23 has been prepared to show the average yield per acre of these various fields. The total number of treated and untreated acres under observation at the end of the season was

Table 23. Alfalfa-Seed Production on Treated and Untreated Fields, Northern Minnesota, 1942

Method of treatment	Acres under observation end of season	Acres not included in production figures	Acres included in production figures	Average yield per acre		Percentage of acreage yielding less than 50 pounds per acre
				Pounds	Bushels	Per cent
Untreated	177.50	....	177.50	49.01	0.81	61.40
Thoroughly burnt-over	143.00	14.5	128.50	94.22	1.57	9.33
Partially burnt-over	124.00	7.0	117.00	52.96	0.88	38.46
Cultivated	121.75	34.0	87.75	122.88*	2.04*	4.55
Burnt-over and cultivated	63.00	8.0	55.00	130.38	2.17	20.00
Total	629.25	63.5	565.75			

* See pages 74-75.

FIG. 15. Mature alfalfa on thoroughly burnt-over field

629.25. Some of this acreage, 63.5 acres, was not included in the production figures. Thirty acres could not be harvested because of rain. No final report on seed yield was obtained for 16 acres. Some thoroughly treated alfalfa (17.5 acres) was not worth harvesting. It had a luxuriant growth, bloomed profusely, and was relatively free from mirids. However, the plants lodged badly during June before the pods formed and they remained in this condition. The thorough burning which had been given these fields may have stimulated growth and thereby predisposed the plants to lodging. Gypsum had been applied to 3 acres of already fertile land during the spring of 1942 and this, no doubt, accelerated the lodging process. Alfalfa lodging was common in 1942. Frequent rains were probably responsible for a large portion of the rank growth. Heavy rains beat down some plants and frequent showers kept others weighted down. The rains were often attended by high winds which blew the plants over. Lodged fields were carefully examined and it was noted that, where scattered bunches were supported upright, seed pods set on. This was also true in lodged portions of other fields. It was the opinion of the writer and of the majority of the alfalfa-seed growers that, when alfalfa lodges preceding pod formation, seed production is negligible. Where lodging occurred after pod formation was well under way, seed production was fair but many pods molded.

Although the separator is still in use in northern Minnesota, most alfalfa seed is harvested by means of a combine. First, the alfalfa (figure 15) is cut with a mower which throws it into a windrow. The alfalfa dries sufficiently for combining in approximately one week, provided the weather is favorable.

As the combine is drawn along the windrow by a tractor, it collects the alfalfa and feeds it over a conveyor into the threshing mechanism. One or two men can operate a combine.

Maturation of alfalfa seed in general was three or four weeks later in 1942 than in 1941. Harvesting was begun in early August, 1941, and in early September, 1942.

SEED PRODUCTION ON UNTREATED FIELDS

Untreated alfalfa available to this study for seed production records totaled 177.5 acres on which the average was 49.01 pounds or 0.81 bushels per acre (table 23). This is, coincidentally, very

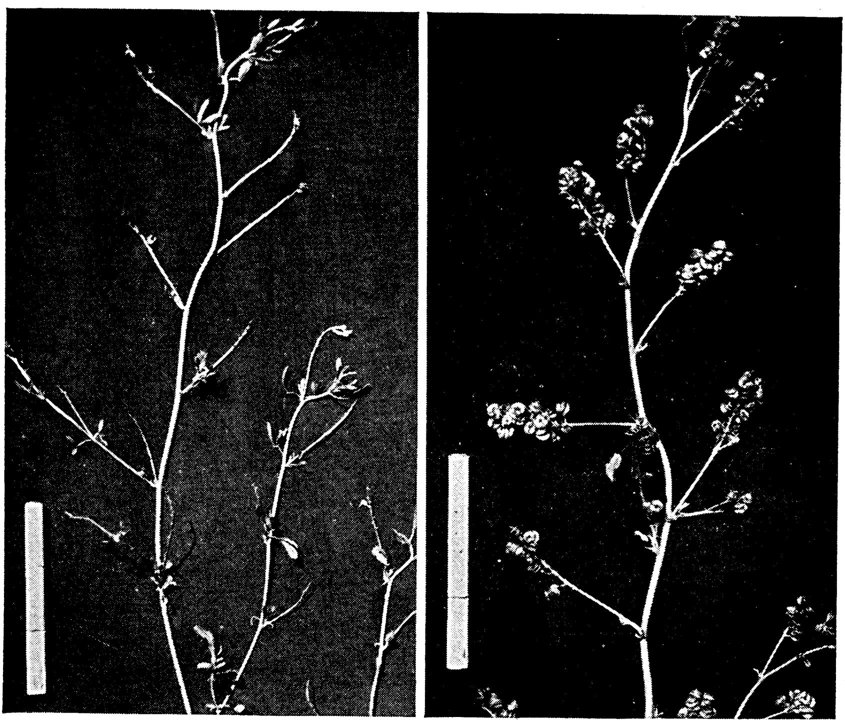

FIG. 16. Left: Alfalfa from an untreated field; crop was a complete seed failure
Right: Pod formation on alfalfa in a thoroughly burnt-over field
(White object at left of each picture is three inches long)

near the average state yield of 0.80 bushels in 1941 and 0.90 bushels per acre in 1942.

Thirty-three per cent was a complete failure and the plants appeared similar to the one shown in figure 16, left; 61.4 per cent averaged less than 50 pounds per acre.

Of all untreated alfalfa, new seeding on new ground was most productive and averaged as much as 125 pounds per acre on three farms in Lake of the Woods County.

SEED PRODUCTION ON THOROUGHLY BURNT-OVER FIELDS

Seed set and seed production were carefully observed in 128.5 acres of thoroughly burnt-over alfalfa.

Buds and flowers developed normally and pods formed well in nearly all of the fields (figure 16, right). Seed formation was in an advanced stage in a few fields by August 10. At this time it seemed that some alfalfa would average as much as 400 pounds per acre since the seed pods were numerous and large. However, the highest yield for a single field was 225 pounds (3.75 bushels) per acre. The average yield per acre in all thoroughly burnt-over fields was 94.22 pounds or 1.57 bushels per acre (table 23).

Of the 128.5 acres thoroughly burnt-over, 41.24 per cent produced 100 pounds or more per acre, whereas 9.33 per cent yielded less than 50 pounds per acre.

SEED PRODUCTION ON PARTIALLY BURNT-OVER FIELDS

Production records are included for 117 acres of alfalfa classed as partially burnt-over. In mid-June, the vegetative growth was good and flowers were numerous. By early July, there was a dropping of flowers, obviously due to mirid injury. It was apparent at an early date that these fields would not yield as well as the thoroughly burnt-over fields. The yield per acre averaged 52.96 pounds or 0.88 bushels (table 23).

Only 13.67 per cent averaged more than 100 pounds per acre and a large percentage, 38.46 per cent, produced less than 50 pounds per acre.

SEED PRODUCTION ON CULTIVATED FIELDS

The average alfalfa-seed yield of 122.88 pounds (2.04 bushels) per acre in the fields which were cultivated is not typical since this average yield was reported mostly from acreage that has produced fair to good seed the past several years though, of course, the majority of the seed fell below the amount produced in earlier years. All of the 87.75 acres of alfalfa were grown in Beltrami County. Seventy-one acres were grown on one farm near the shore of Upper Red Lake. This grower reported that, in 1940, his alfalfa had produced an average of 500 pounds per acre with the exception of 7 acres which yielded 900 pounds per acre. Seed on this farm would have had a good yield in 1941, but there was a big loss due to wet weather and the average yield fell to 350 pounds per acre. In 1942, one field produced 400 pounds to the acre; another, 120 pounds; and the rest only 100 pounds to the acre. This made an average yield on this farm for 1942 of 128.16 pounds per acre. This gradually reduced production is similarly true of the remaining acreage.

The growers of the alfalfa on 81 acres, or 92 per cent of the total of 87.75 cultivated acres included in the production figures, had made cultivation a practice for several years.

SEED PRODUCTION ON BURNT-OVER AND CULTIVATED FIELDS

There was a higher yield of seed per acre in burnt-over and cultivated fields than in any of the other treated fields. Of the 55 acres included in the production figures, 25 had been thoroughly burnt-over and 10 had been burnt-over well. The average yield on these 35 acres was 145.14 pounds (2.42 bushels) per acre while on the remaining 20 acres the average was 102.05 pounds (1.7 bushels).

The average yield was 130.38 pounds per acre or 2.17 bushels for all burnt-over and cultivated alfalfa.

ALFALFA SEED—1942 CROP

According to the United States Department of Agriculture *(23)*, the amount of alfalfa seed produced in the United States in 1942 is the smallest in 10 years. It states, however, that there seems to be sufficient seed carried over to meet the 1943 domestic and export needs, except for the northern-grown alfalfa.

It was a most unfavorable year for alfalfa-seed production in the counties included in this study. The season as a whole was wet and cold and there were late spring and early fall frosts.

The mirid population was less, because of the adverse weather conditions, but was proportionately numerous to do considerable damage to an already weakened crop.

When seed was examined even before it was harvested, some was found to be dark-colored and shriveled. This undesirable condition may have been caused by one or by several factors.

The weather, no doubt, was responsible to a large degree. Growers stated that seed often turns dark when the season has an unusual amount of rainfall. It is possible, too, that excessive rainfall during the growing season may have stimulated plant growth, thus diverting the food to plant-tissue formation instead of storing it in the seeds and causing them to be full and plump. It is probable, also, that frost injury contributed largely to this condition. Seed was late in developing and most of it was not ripe until mid-September. A killing frost occurred August 24, 1942, in northern Minnesota and was known to be particularly severe in Beltrami and Clearwater counties.

There is only a slight possibility that insects, Miridae in particular, were responsible for this damage to alfalfa seed. The bug population was exceptionally low in a number of the fields where seed was dark and shriveled.

Some dark and shriveled alfalfa seed harvested in northern Minnesota in 1942 resembled chalcid-infested alfalfa seed. During the summer, chalcids (*Bruchophagus funebris* Howard, Hymenoptera) were observed in alfalfa, but there was no indication of them in the harvested seed which was examined.

The small, shriveled seeds reduced the yield materially. According to reports from the growers, as much as 40 to 50 per cent of the seed fell in this group. Samples obtained by the writer substantiated these reports.

Some alfalfa seed growers believe that much of the dark and shriveled seed is viable. They report fair results with it.

The Minnesota State Seed Testing Laboratory at University Farm, St. Paul, ran germination tests on small samples of Grimm alfalfa seed for this study. The number of seeds per sample was 100; a larger number would have provided more conclusive evidence. The results of these tests are summarized in table 24.

Table 24. Results of Germination Tests Run on Grimm Alfalfa (Tests Conducted for Eight Days)

Grimm seed	Per cent			
	Hard	Abnormal	Dead	Germination
Canadian Registered—1940	6	4	1	89
Minnesota Second-grade—1941	10	1	1	88
Minnesota, apparently normal—1942	76	2	2	20
Minnesota, green-shriveled—1942	62	2	16	20
Minnesota, brown-shriveled—1942	1	19	50	30

There was little difference in the amount of germination of Canadian Registered Grimm and of Second-grade Minnesota Grimm; both responded favorably.

Carefully selected, normal-appearing Grimm seed of the 1942 Minnesota crop germinated poorly. It contained 76 per cent hard seeds or seeds which do not germinate readily but may do so later. Approximately 85 per cent of the hard alfalfa seed is said to germinate eventually. A small per cent of this hard seed is often considered a good quality since it tends to insure additional plant growth over a period of years.

Green, shriveled seed reacted similarly to Second-grade Minnesota Grimm. Badly shriveled, brown seed seems of little value. Less than one third of it germinated normally.

Summary and Conclusions

Adelphocoris lineolatus (Goeze), the alfalfa plant bug, was first recorded for Minnesota in 1933. Since then its distribution has become state-wide on alfalfa and sweet clover. *A. lineolatus,* an old-world species known as the lucerne leaf bug, has caused serious damage to alfalfa in Europe. The present investigation of its life history and habits was undertaken to determine whether there was any correlation between its occurrence in Minnesota and the reduced alfalfa-seed yields here since the early 1930's.

There are two generations of *A. lineolatus* each year in Minnesota. It overwinters in the egg stage in the stems of alfalfa. The eggs hatch in early May. The nymphs and adults feed on the buds, flowers, and immature pods of alfalfa. Field observations and cage studies demonstrated conclusively that *A. lineolatus* is responsible for much of the bud blast, flower fall, and pod injury to Minnesota alfalfa. Histological studies of flowers injured by *A. lineolatus* showed that cells near the feeding punctures, especially in the ovary and ovules, were affected. Necrosis of injured cells was localized around the feeding punctures at first, but later spread to other parts of the individual flower. Cell disintegration was obvious in the ovary and ovules 18 hours after mirid feeding. The injury is thought to be mainly phytotoxic although there is naturally a small amount of mechanical injury.

The spread of *A. lineolatus* throughout Minnesota since the early 1930's coincided with the reduction in alfalfa-seed yields.

Several species of Lygus bugs, *Lygus oblineatus* (Say) in particular, are also common on alfalfa in Minnesota. These bugs overwinter as adults and are known to have many host plants. Their injury to alfalfa is similar in nature to that caused by *A. lineolatus* as was shown in cage and field studies.

Adelphocoris rapidus (Say), the rapid plant bug, is found on alfalfa in diminutive numbers. It resembles *Adelphocoris lineolatus* in life history and habits.

In addition to mirid injury to alfalfa flowers, studies showed that approximately 35 per cent of all flowers tripped, cross-pollinated, and caged free from mirids failed to set seed as a result of causes other than insects. In the field the per cent of flower fall attributable to lack of tripping, lack of fertilization, and to other little-known causes would be higher still.

Cultural control methods were employed in some northern Minnesota alfalfa fields during 1942. It was shown that thorough burning-over of alfalfa fields, in the early spring before the mirids became active, effectively reduced the *A. lineolatus* population as well as the populations of *A. rapidus* and *Lygus* spp. Where burning was not thorough, the mirid population was reduced only slightly. Cultivation alone was less effective in reducing the mirid populations than burning. Some fields were burnt-over and cultivated. Where the burning was thorough, the mirid populations were materially reduced.

Mirid control experiments with pyrocide dust and sulphur, on several one-half acre plots of alfalfa heavily infested with mirids, indicated that pyrethrum had more knockdown than killing value and that sulphur had little or no effect on these insects. The alfalfa seed in the chemically treated plots showed no increased yield when compared with the yield from untreated check plots.

Cage and field studies demonstrated conclusively that *A. lineolatus, A. rapidus,* and *Lygus* spp. are responsible for flower fall in alfalfa. This damage is sufficient to account for the reduction of the alfalfa-seed crop in this state.

Similar studies have also shown that *A. lineolatus* is more important than the other species of Miridae present. This is supported by the fact that, although *A. rapidus* and *Lygus* spp. have been in Minnesota many years, reductions in alfalfa-seed yields were not reported generally until *A. lineolatus* had been introduced.

Of the control methods tried, thorough burning-over of alfalfa fields in the early spring was the most effective in destroying the overwintering stages of *A. lineolatus, A. rapidus,* and *Lygus* spp.

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